SUBCOURSE EN5464

EDITION B

US ARMY ENGINEER CENTER AND SCHOOL

QUARRY OPERATIONS II

"Let us try"

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

Quarry Operations II

Subcourse Number EN5464

Edition B

United States Army Engineer School
Fort Leonard Wood, MO 65473

Four Credit Hours
Edition Date: September 1992

Subcourse Overview

This subcourse will enable you to analyze a rock crushing requirement, select proper equipment, choose a suitable site for a rock crusher complex, plan the layout of a rock crusher complex, and evaluate the operation of the complex. You will also be able to demonstrate the ability to estimate the production rates for quarry and rock crushing equipment.

There are no prerequisites for this subcourse.

This subcourse reflects current doctrine when this subcourse was prepared. In your own work, always refer to the latest publications.

The words "he", "him", "his", and "men", when used in this publication, represents the masculine and feminine genders unless otherwise stated.

TERMINAL LEARNING OBJECTIVES

ACTION:	You will analyze a rock crushing requirements, select the equipment and site for the rock crushing complex, plan the layout and evaluate the operations; demonstrate ability to estimate the production rates for quarrying the rock crushing equipment.
CONDITIONS:	Given this subcourse, a No. 2 pencil, paper and an ACCP Examination Response Sheet.
STANDARD:	To demonstrate competency of this task, you must achieve a minimum of 70% on this subcourse examination.

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LESSON 1

ANALYZE A ROCK CRUSHING COMPLEX

LESSON DESCRIPTION:

This lesson will teach you how to analyze a rock crushing requirement and select the appropriate equipment. You will also learn how to select a site and design a layout for a rock crusher complex, and evaluate the operation of the complex.

TERMINAL LEARNING OBJECTIVES:

ACTION: Identify the rock crushing equipment, select the equipment and a site for the rock crusher complex, plan the layout of the complex, and evaluate the operation of the complex.

CONDITIONS: Given this subcourse, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.

STANDARDS: Demonstrate competency of the task skills and knowledge by responding correctly to 70% of the examination questions.

REFERENCES: The materials contained in this lesson was derived from TM 5-331-C and TM 5-332.

INTRODUCTION

Many engineer operations require the supply of aggregates and other quarry materials for construction use. As a military engineer you should be familiar with the product requirements and equipment necessary to produce finished aggregate from raw quarry material.

Equipment is provided in the military supply system to enable units to meet their aggregate production requirements. Of this equipment, the crushing equipment is usually the critical item. It must be capable of receiving reduction and processing, and producing the finished aggregate in sufficient quality and quantity to meet the job requirements.

You will learn how to analyze a rock crushing requirement and select the appropriate equipment. You will also learn how to select a site and design a layout for a rock crusher complex and how to evaluate it's operation.

This lesson has two parts:

- Analyze a Rock Crushing Requirement and Select the equipment.

- Select the site and plan the layout for the Rock Crusher Complex and evaluate it's operation.

Frequently, there is not sufficient time to properly design and lay out a rock crushing facility. This is usually due to the fact that a need for crushed stone exists before the crusher is set up. Often the errors made in the initial design and layout of the installation are of such magnitude that production is affected considerably. In extreme cases, the plant must shut down to make the necessary corrections. Three areas should be considered in the plant design and layout phase of construction. The areas are equipment selection, site selection, and plant erection.

Learning Event 1
DESCRIBE ROCK CRUSHING REQUIREMENTS AND EQUIPMENT SELECTION

Your selection of equipment for a rock processing facility is accomplished after a thorough study and evaluation of five factors. These five factors are:

- mission to be accomplished,
- equipment available,
- raw material to be crushed;
- the amount and type of processing required, and
- a chart depicting the anticipated flow of materials through the facility.

These factors make up the rock crushing requirement for your operation.

MISSION

The mission of your unit will indicate the size and amount of rock product desired and the time given to accomplish this task. The size product desired may be given as a maximum top size or as a graded size product:

- Maximum Top Size (Example): 7,000 tons of 3-inch minus material.
- Graded Size Produce (Example): 7,000 tons of aggregate to meet the following specifications:

Size	Percent Passing
1-inch	100 percent
3/4-inch	90-100 percent
1/2-inch	20-55 percent
3/8-inch	0-15 percent
#4	0-5 percent

The mission will also indicate if washing is required or if sand should be reclaimed from the fines generated through the crushing action.

EQUIPMENT AVAILABLE

You should make an assessment of the equipment available for your facility. This should include the unit's TOE equipment as well as equipment from supporting organizations. This assessment should also include the availability and skills of the personnel to operate the equipment.

RAW MATERIAL

The type and size of the raw material to be crushed will determine the type of crusher that you will need to process the rock. If the raw material is quarry

run rock, a primary jaw crusher will be needed for the initial stage of reduction in the plant. If the raw material is smaller river run gravel, the secondary roll crusher may be the only crusher needed for the crushing operation.

PROCESSING REQUIRED

The extent of the processing required to produce the desired aggregate size will indicate the amount and types of equipment you need. For crushing 4-inch minus base course material, a primary jaw crusher may be sufficient to achieve the desired results. If 1-inch minus aggregate is to be produced from quarry run rock, a primary jaw crusher and a secondary roll crusher will be required. If the crushed aggregate must be washed, a washing unit will be needed. If an existing stockpile of aggregate must be sorted into different sizes of aggregate, a screening unit will be needed to accomplish this task satisfactorily. You must determine the nature of the processing to be accomplished in order to select the necessary equipment to do the job.

FLOW CHART

The last step in the equipment selection phase of plant layout and design is to chart the flow of material through the plant. The flow chart should start where the raw material first enters the plant and terminate at the stockpile of finished product. This chart is useful in determining the amount of conveyors that will be needed to transport the rock between the various pieces of equipment, and between the equipment and the stockpiles. During this phase of planning you should determine the equipment configuration within the facility. You should also consider the amount and types of equipment that will be needed to load haul units, keep stockpiles maintained, and the amount of equipment that will be needed to construct the facility.

Learning Event 2
IDENTIFY BASIC PROCESSING COMPONENTS OF ROCK CRUSHING EQUIPMENT

The amount or degree of processing required to produce suitable aggregate materials for construction purposes depends upon the nature of raw materials available and the desired characteristics of the end product. Only four basic functions are to be accomplished in even the largest and most elaborate operations. These functions are:

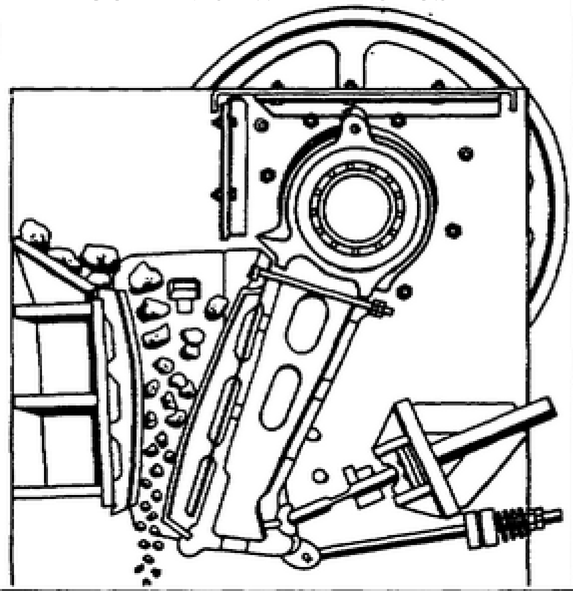
- particle size reduction by crushing,
- separation into particle size ranges by screening,
- elimination of undesirable materials by washing, and
- movement of the material from one place to another.

Special equipment has been designed and is available to accomplish each of these basic functions.

JAW CRUSHERS

The Dalton, single toggle, overhead eccentric type jaw crusher is standard. Although of different sizes, all jaw crushers in the military supply system are of the same basic design (Figure 1).

FIGURE 1. JAW TYPE CRUSHER



Function and Operation. The jaw crusher receives raw material from the pit or quarry and reduces it to a smaller particle size. Material to be crushed is introduced into the jaw cavity and is gradually reduced by a series of elliptical-downward crushing strokes and is discharged out the bottom of the jaw assembly. The product size is determined by the product setting adjustment made at the discharge end of the jaw plates.

Production Considerations. The hourly rate of production to be obtained from a given size jaw crusher is dependent upon a number of variable factors:

- The toughness of the raw material.
- The product setting.
- The reduction ratio. (The size of the material fed to the crusher compared to the product size.)
- The gradation of raw material.
- The extent of wear to the corrugated surfaces of the jaw plates.
- The rate of feeding.

Due to the characteristic irregular shapes and unwieldy nature of quarry run rock, several feeding problems may develop which will drastically reduce production. Some common operational problems are *blocking*, *bridging*, *choking*, and *packing*.

Blocking occurs when an oversize rock particle settles over the jaw cavity opening and stops the flow of incoming material. The jaws continue to operate but no crushing takes place. To prevent blocking, the maximum size of material should be 2 inches less than the jaw crusher size. Blocking can best be controlled or eliminated by using a scalping grizzly to prescreen material. *For optimum production, the ideal feed size is 75 percent of the jaw size.*

Bridging occurs when two rock particle, within the maximum size limitations, arrive at the same time. The two rocks interlock and bridge the jaw cavity opening. When this occurs, all production stops. When large pieces approach the opening, they should be fed individually to prevent bridging.

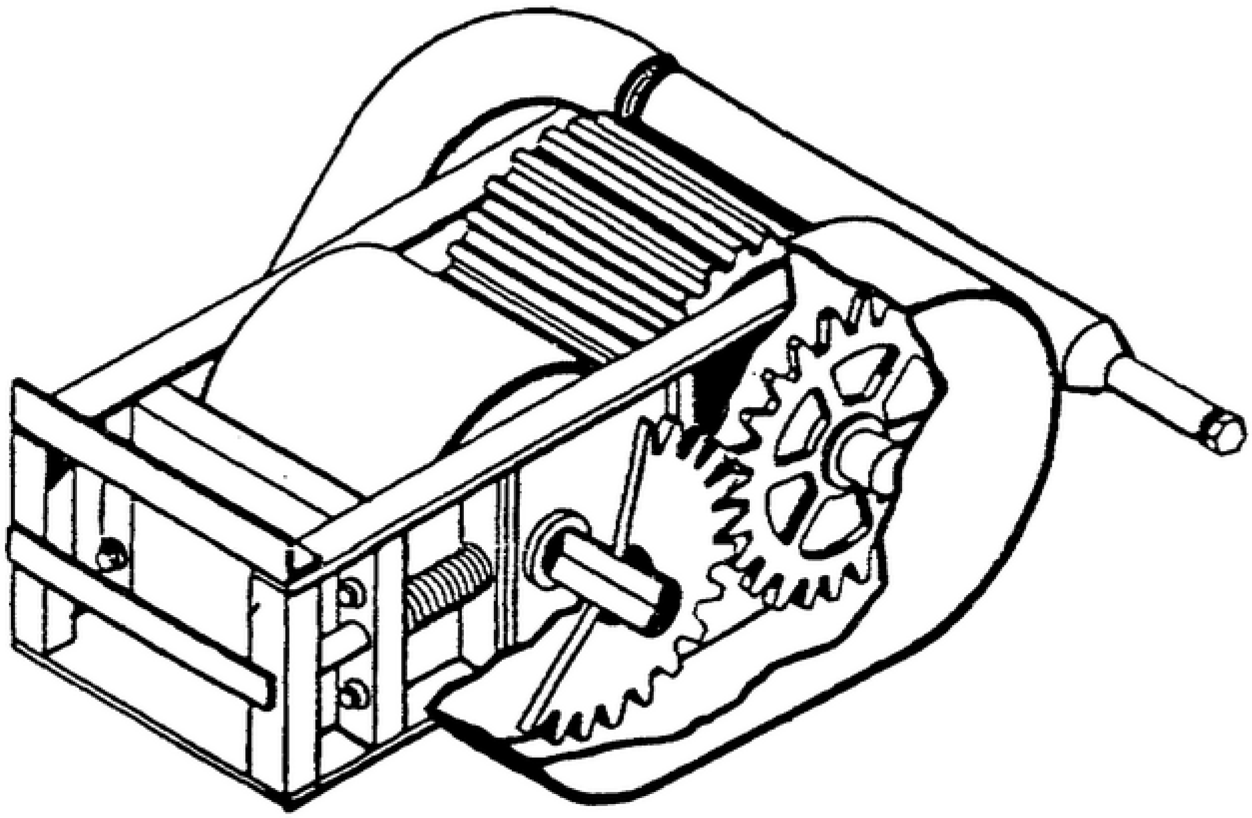
Choking occurs when the jaw chamber is continually overfilled. This creates an overload condition and causes the engine to lug down and may damage equipment. For optimum production, the operator should try to keep the jaw chamber 75 percent full.

Packing occurs when feed material cakes and packs in the crushing chamber. Plastic material, such as clay, may become sticky and cause this problem. Packing can become so severe as to completely stop production. This will severely damage the jaw crusher assembly. Packing can be reduced or eliminated by prescreening or prewashing the material. The most practical solution in most cases is to thoroughly wet down the material. Then process the material, though it's almost in the form of a slurry.

DUAL ROLL CRUSHERS

Function and Operation. Roll crushers are used exclusively in the military supply system to accomplish the intermediate stage of reduction of rock (Figure 2).

FIGURE 2. DUAL ROLL CRUSHER



All roll crushers in the Army are dual rolls varying from 24 inches to 54 inches in diameter.

The crusher assembly consists essentially of a set of rolls which revolve toward each other at constant rim speed. Stone particles are reduced in size as they are drawn between the two rolls. Product setting is determined by the spacing between the rolls. It is necessary to set the opening between the rolls slightly closer than the top product size required. With two coarse corrugated shells, the tip to tip setting will produce a product larger than two smooth shells set at the same distance.

Production Consideration. Generally speaking, the same variable factors discussed for jaw crushers will affect the production of roll crushers. By com-

parison, dual roll crushers have a very limited stage of reduction capability. *Stage of reduction is the difference in maximum input and maximum output size of material due to a single crushing action.* Stage of reduction can be expressed in inches or centimeters. A stage of reduction of 3 inches (7.6 cm) would indicate a 3 inch (7.6 cm) reduction in maximum particle size. This reduction capability is a function of the diameter of the rolls, and the nature of the roll shell surface. Therefore, every different size and combination of roll shells has a somewhat different stage of reduction capacity. For this reason the maximum size of material to be fed to a dual roll crusher is critical.

The maximum allowable feed size is the sum of the stage of reduction capability and the product setting. If the maximum feed size is exceeded, several unsatisfactory results are likely to occur:

- Retarded production.
- Excessive roll shell wear.
- Excessive long and flat particles.

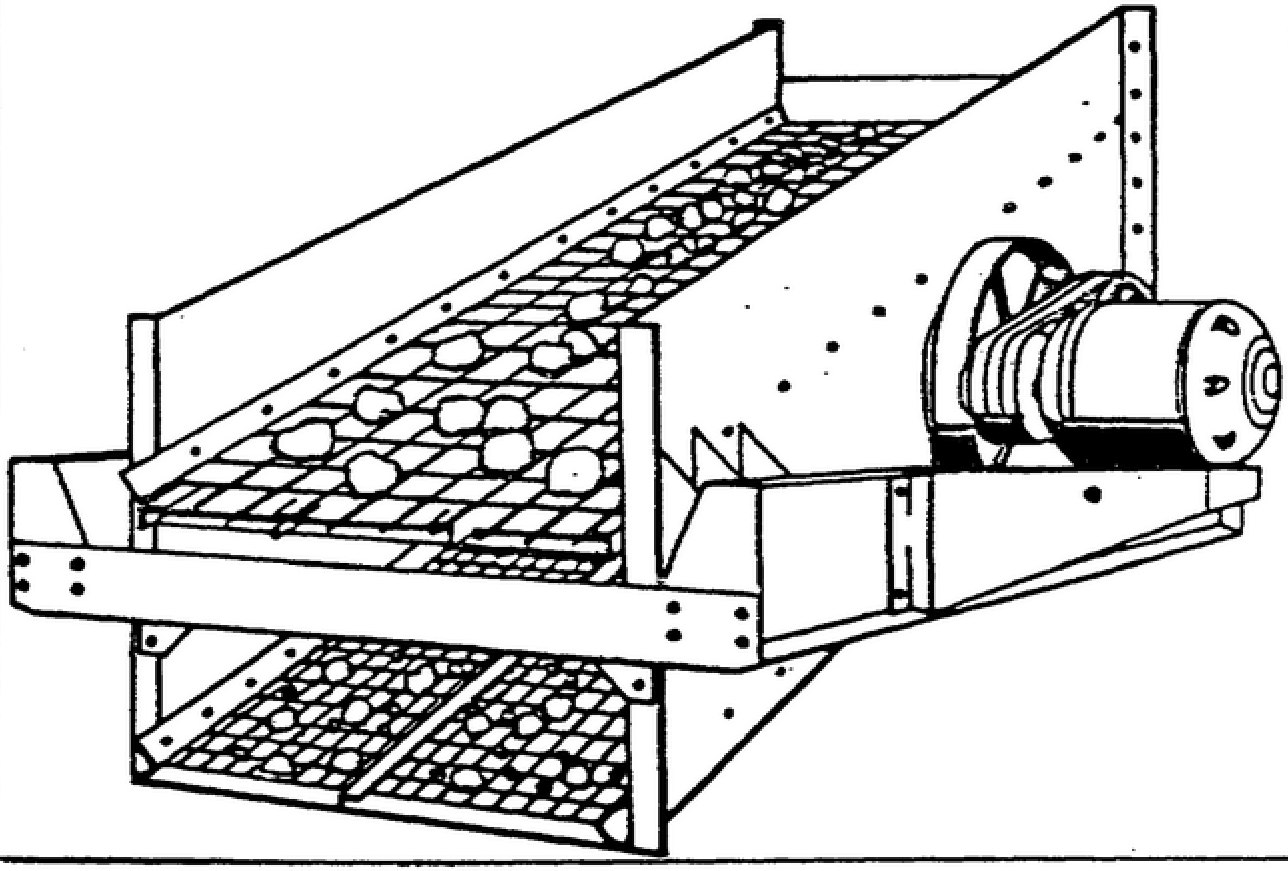
SCREENS

Function and Operation. In all but the most basic and fundamental crushing operations, the crushed rock particles are separated into two or more particle size ranges. This is accomplished by the use of screens. Screens are also used to scalp off oversize rock and to screen out fines. This enables you to direct certain selected material to receive special or additional processing. Certain material may also be directed to bypass processing that is not required.

Screens consist of two, three, or four layers or decks of open mesh screen wire cloth mounted one above the other in a rectangular metal box (Figure 3). The screen surface is vibrated to aid sorting. Material is fed at one end and is separated into size ranges as it is passed over the screening surface. The screening process is based upon the simple premise that particle sizes smaller than the screen cloth opening size will pass through the screen and oversized particles will be retained.

Production Considerations. In order to obtain good efficiency and high capacity, stratification of the feed material must occur rapidly as the material is passed over the screen surface. This ensures that the smaller particles move quickly to the bottom and find their way through the screen openings while the larger oversized particles are carried to the top of the feed stream where they are retained and directed off the end of the screen. The precise performance characteristics desired of specific screens are obtained by varying *the degree of inclination, frequency and amplitude of stroke, and the direction of throw.* Screens may be horizontal or inclined up to about 20 degrees and vibrate at 850 to 1,250 strokes per minute depending upon the particular application.

FIGURE 3. MECHANICAL VIBRATING SCREEN BOX



- Capacity. Capacity is the rate in tons per hour at which a screen produces (passes) the material desired. The capacity of a screen is *not* the total amount of material that can be fed and passed over the surface, but the rate at which it separates desired material from the feed.

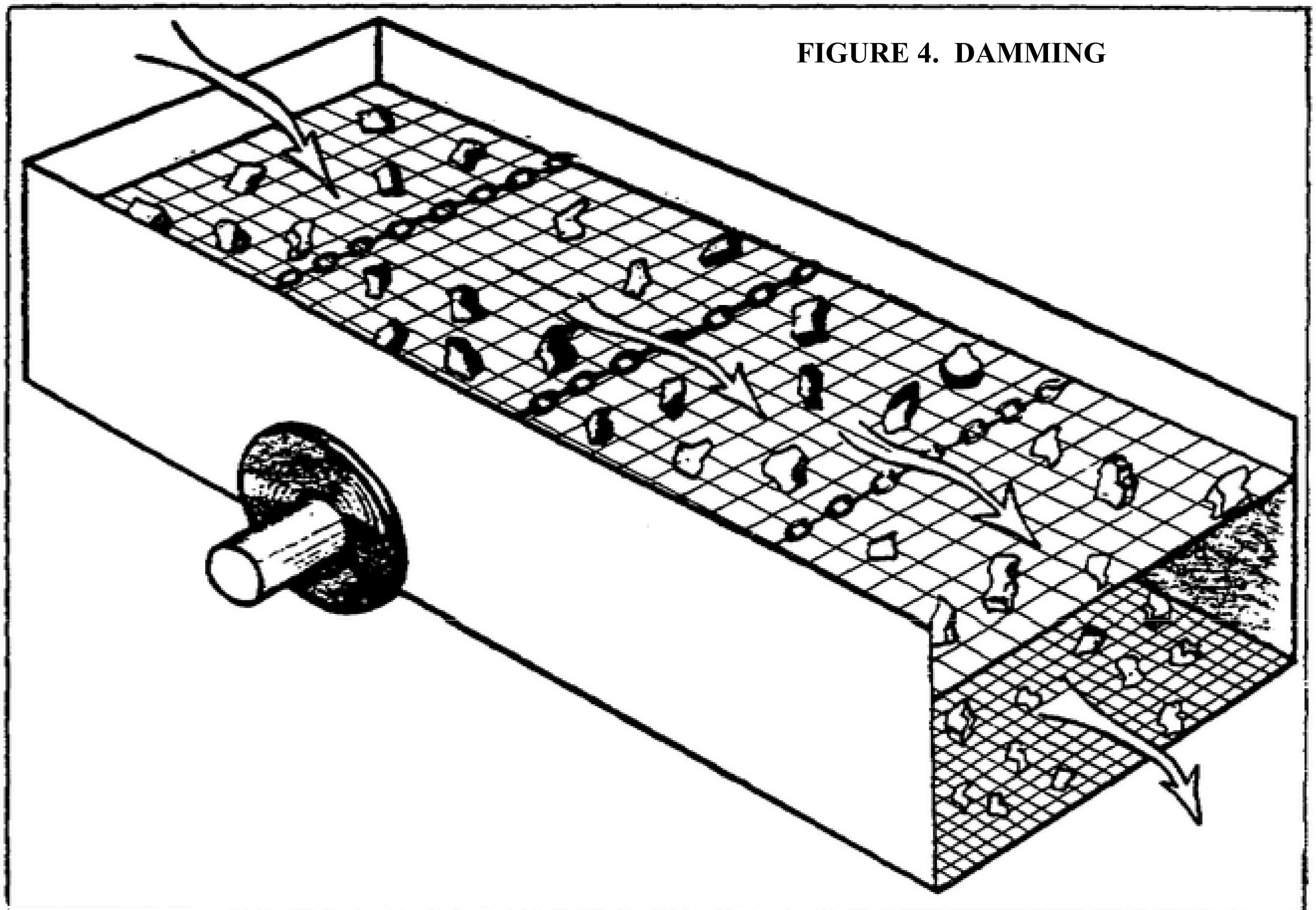
- Feeding Materials to Screens. Care must be taken to spread the flow of material evenly across the full width of the screen. *The thickness of the bed of feed material should be approximately four times the screen opening size.* If this is exceeded, the screen will be overloaded, the vibrations dampened, and the finer particles will be unable to find their way to the screen wire openings. If, on the other hand, insufficient material is fed, the total capacity of the screen is not being used.

- Variable Factors. There are numerous factors that will affect the performance of screens. Some examples of these are shape, weight, and gradation of particles, degree of inclination and vibration, type of wire screen cloth, position of the screen within the deck, and wet screening (washing). Experience and testing have proven that the effects of the most significant of these can be calculated, and an accurate estimate of actual screen capacity can be made. Since these factors will differ, the capacity of each screen must be calculated separately. These instructions will be given in Lesson 2.

Expedient Screen Manipulation. In certain aggregate producing operations gradation specifications are stringent and equipment processing capability is limited. In these situations it is difficult to produce material size ranges that will fall entirely within the limits of specifications. After every crusher adjustment and screen size selection possibility has been exhausted, gradation of the product can be influenced to a certain extent by an expedient means. *Damming* and *splitting* are the two expedient means available.

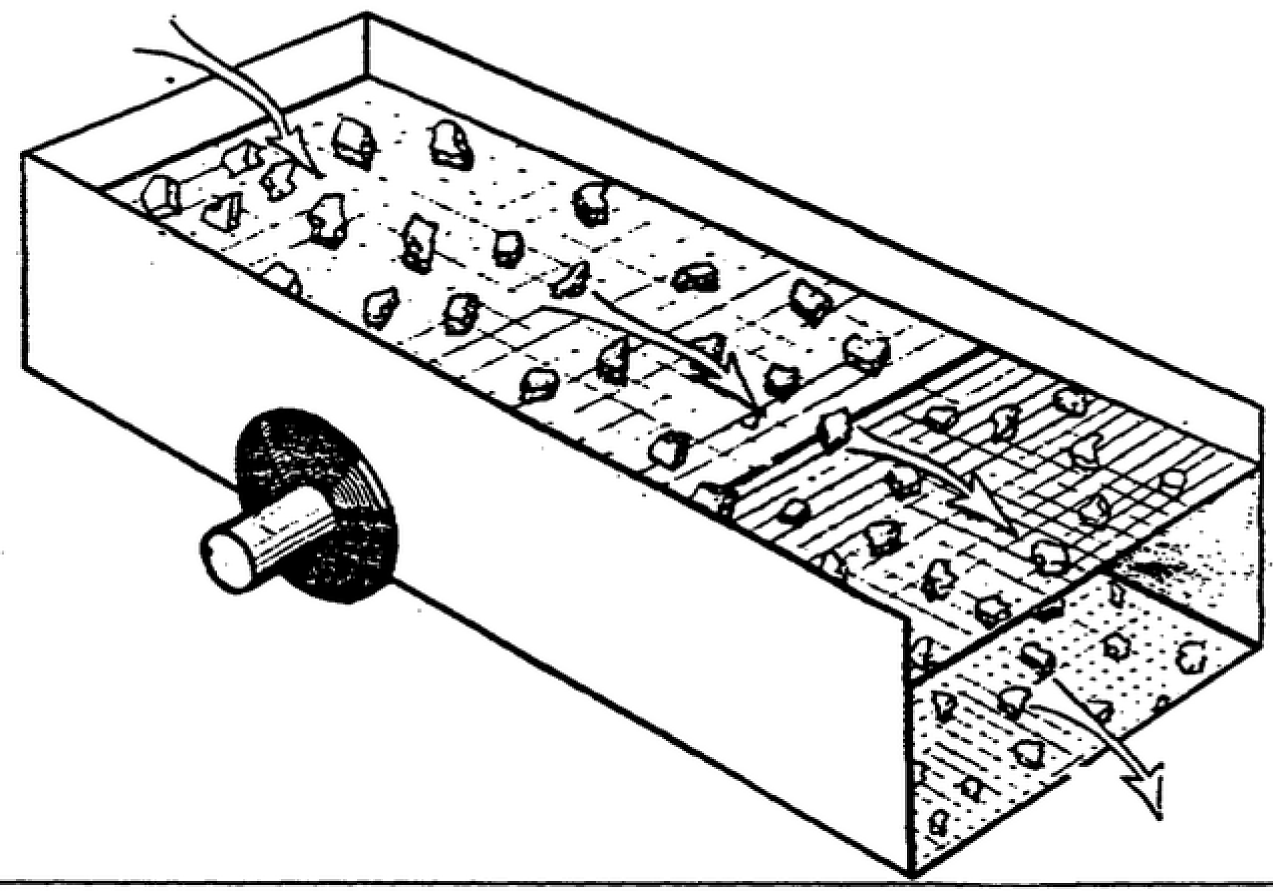
- Damming: One or more lengths of chain may be secured to extend on top of the screen surface at 90 degrees to the flow of material (Figure 4). This will create a damming effect, retarding material flow, and keeping the particles exposed to the screen openings longer. This ensures that the maximum of the upper sized particles is obtained. The result is a greater proportion of larger sized particles to fines in the product.

FIGURE 4. DAMMING



- Splitting: A screen section with somewhat smaller openings can be installed in the lower end of the screen box (Figure 5). In this case, the smaller particle size will pass either section of the screen readily, while the screen area that will pass the larger sized particles has been reduced by one-half. This will result in a greater proportion of fine particles to coarse in the product.

FIGURE 5. SPLITTING



- Limitations: When these expedients are applied to the top screen in a dosed circuit crushing system, the effects will be compounded. Damming will result in less oversize material being scalped off and sent through the dual roll crusher. This means that somewhat less additional fines will be produced. *Splitting* results in more material being sent to the roll crusher so that more additional fines will be generated. While these actions will enable close control over graded sizes produced, overall production rates may be reduced to the same extent that screen capacity is decreased.

MECHANICAL FEEDERS

Function and Operation. The crushers, screens, and washing equipment are the key items in aggregate production operations. Effective operation, however, requires some means of regulating the flow of material being processed, transporting it from one component of the plant to another, and conveying it to the stockpile. Mechanical feeders and rubber belt conveyors are used to accomplish these materials handling functions.

Two types of mechanical feeders are used. These are apron feeders and reciprocating plate feeders. *Apron feeders* are of heavy duty construction and are used to regulate the feed of quarry run rock into the jaw crusher for the initial stage of reduction. The *reciprocating plate feeder* is a smaller feeder and is normally used to regulate the flow of material which has already been reduced in size. It is commonly used to control the rate of flow to secondary crushers, screens and washing

Production Considerations. Methods of Charging Feeders.

Criteria: Materials to be introduced into feeders have to meet certain criteria of size and cleanliness. Certain precautions have to be taken to ensure this.

Selective loading: Selective loading is the loading of select material for transportation to the crushing plant. Its basic purpose is twofold. First, it prevents oversize materials from being sent to the primary crusher with a resultant stoppage of that unit. Second, when the material is to be used for concrete or asphalt aggregate, cleanliness is important to avoid the need for washing the material. In this method, the shovel operator wastes to one side all material that contains extra large pieces of material that is extremely damp and dirty which the screening process cannot handle.

Prescreening of materials: When selective loading is impractical another method called prescreening is used. In many operations prescreening is chosen primarily because of the inherent flexibility it provides. The most common prescreening device is the *grizzly*. This screen is made of heavy bars or rails to eliminate oversized rocks.

Truck Feed: Two levels are normally used for the crushing operation. The quarry run rock is dumped directly onto the apron feeder or into a loading chute by trucks on the upper level. The rock is then processed through the plant and discharged on the lower level via inclined conveyor belt. Alternatives to dual-level operation involve double handling the material. These are acceptable for operations of short duration but are far less efficient for longer operations.

Lifting and Loading Equipment Feed: Where jobs are of a short duration, the use of lifting and loading equipment has become popular. Draglines, clam-shells, and shovels are used for this purpose

CONVEYORS

Function and Operation. Conveyors are used to move material being processed from one component to another and to convey the finished product

into bins, waiting trucks, or onto stockpiles. Rubber belt conveyors are of the fixed or portable type. Fixed conveyors are attached to and are a component of the crushing unit. They are similar in design and work on the same principle as do portable conveyors.

Production Considerations. Three factors--speed, loading, and incline--affect the efficiency of conveyor operation.

- Speed. Most conveyors operate at a speed of approximately 300 feet per minute and have a capacity of approximately 300 tons of material per hour. A reduction in speed will obviously reduce the conveyor capacity while an increase in speed would theoretically increase the capacity. An increase in conveyor speed may also increase wear on the conveyor belt due to increased slippage of the material at the loading point. An increase in speed will also increase the "throw" of the material at the discharge end of the conveyor. In some cases it may be necessary to fit the end of the conveyor with a box or "bang board" so that the material from the belt will fall properly.

- Loading. Proper loading of a belt conveyor is mandatory for efficient operation. This includes placing the load so that it is centered on the conveyor belt. This is a most common problem. *It is always good practice to load a conveyor so that the material strikes the belt in the direction of travel.* When material is to be delivered from a spout or belt to another belt from one side, a transfer box or "bang board" should be provided to facilitate proper delivery on the belt. Loading a conveyor belt on one side will cause it to lean to the opposite side of the support rollers causing excessive belt wear.

- Incline. Portable conveyors can be adjusted to operate at various inclines required by job conditions. The maximum incline is determined by the material carried on the conveyor and varies from about 12 degrees for washed gravel to 20 degrees for loose earth. When the maximum angle is exceeded slippage may occur.

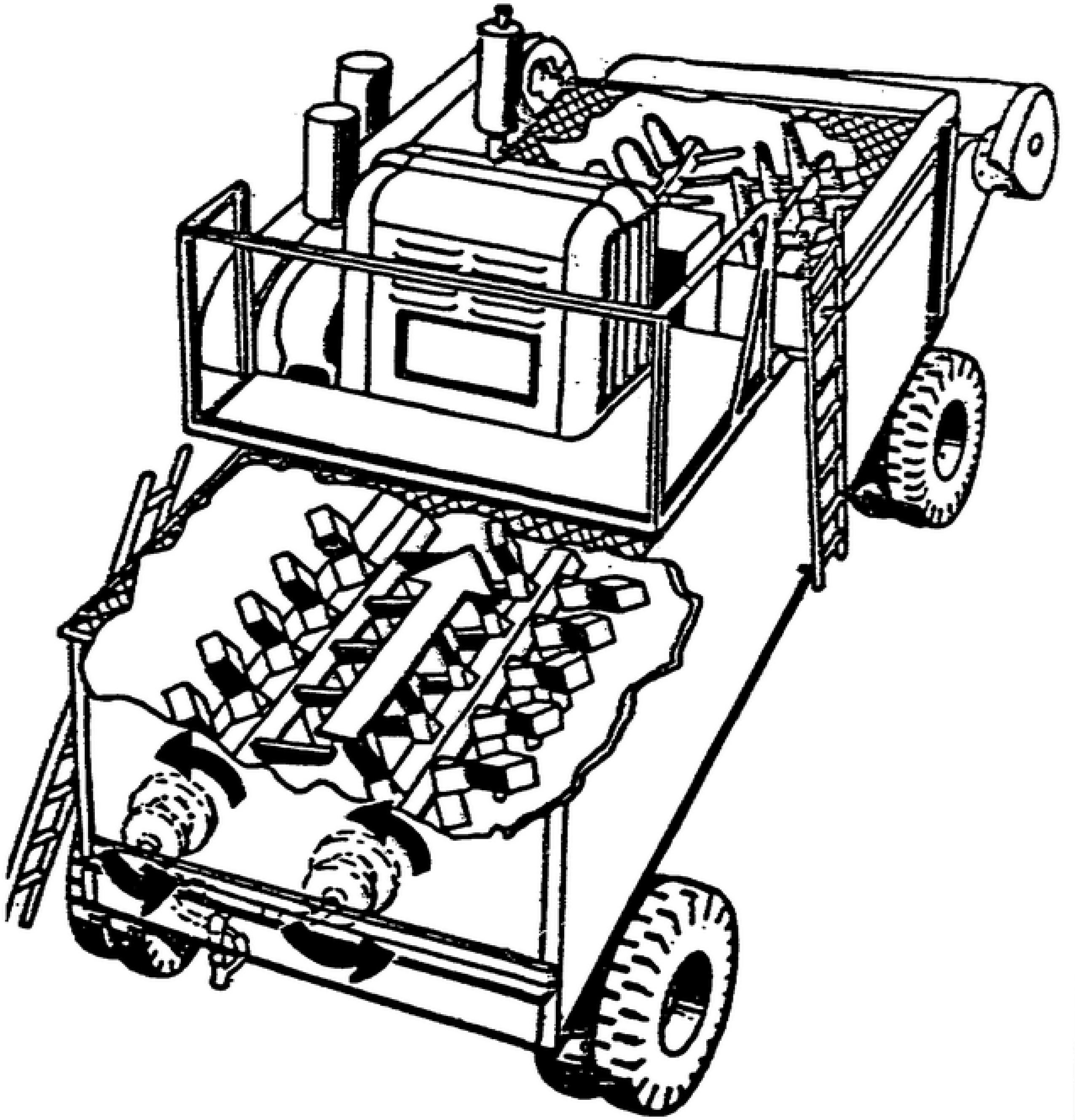
WASHING EQUIPMENT

Construction aggregates sometimes require washing to remove undesirable materials. Military washing equipment includes *revolving scrubbers*, *wet screens*, *log washers*, and *dehydrators*.

Scrubbers are used to move clay, silt, and other undesirables from crushed stone. Wet screening is used to initially wash easily removed material, such

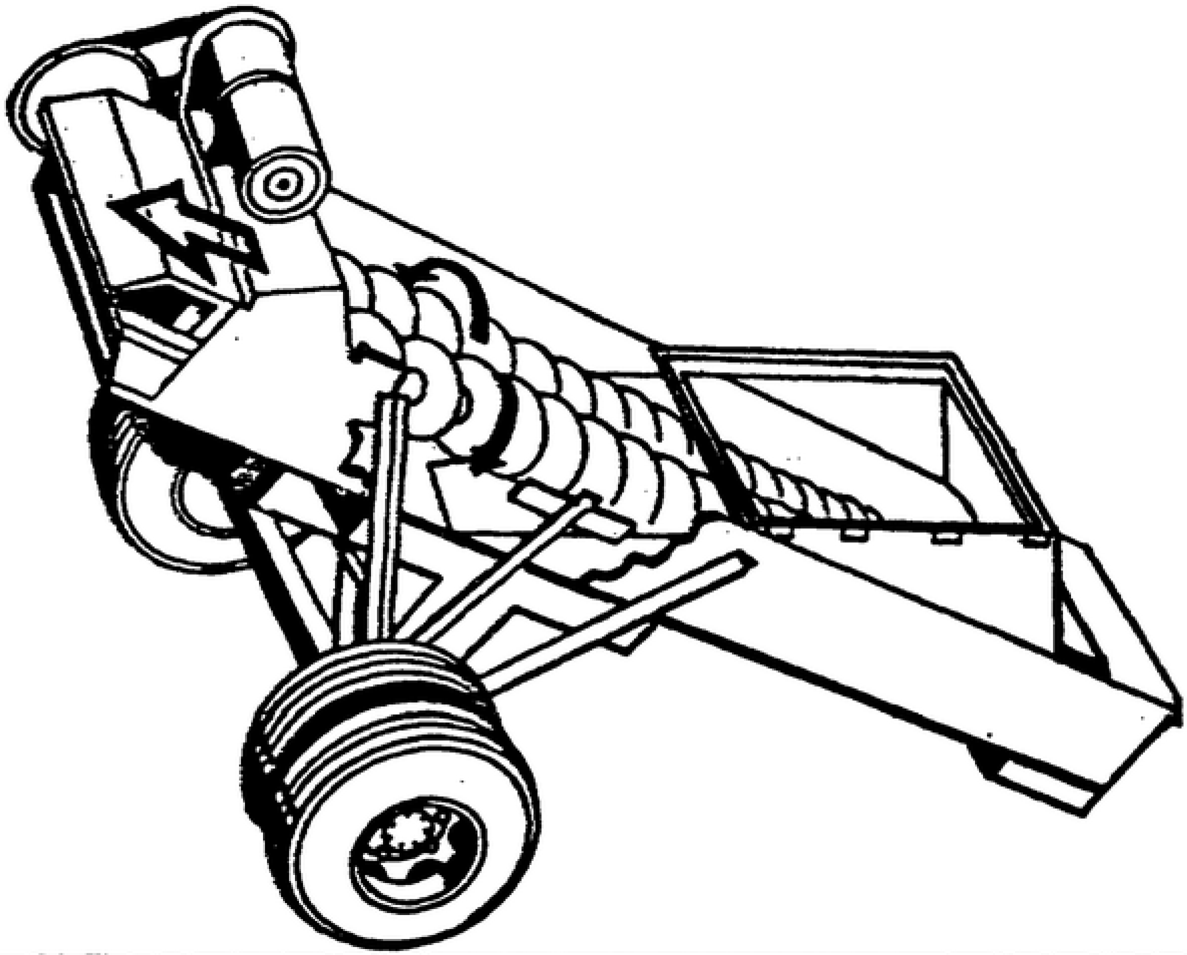
as silt, or to rinse material washed in a scrubber drum. Some material tends to roll up and form balls which must be broken up before they can be removed by the wash water. Log washers are used to do this (Figure 6).

FIGURE 6. LOG WASHER



Sand dehydrators are used for washing fine aggregates and classifying sand. The dehydrator classifies sand through the principle of water turbulence. Therefore, the greater the turbulence, the coarser will be the sand product. As the water turbulence is reduced, the sand product will be progressively finer.

FIGURE 7. SAND DEHYDRATOR



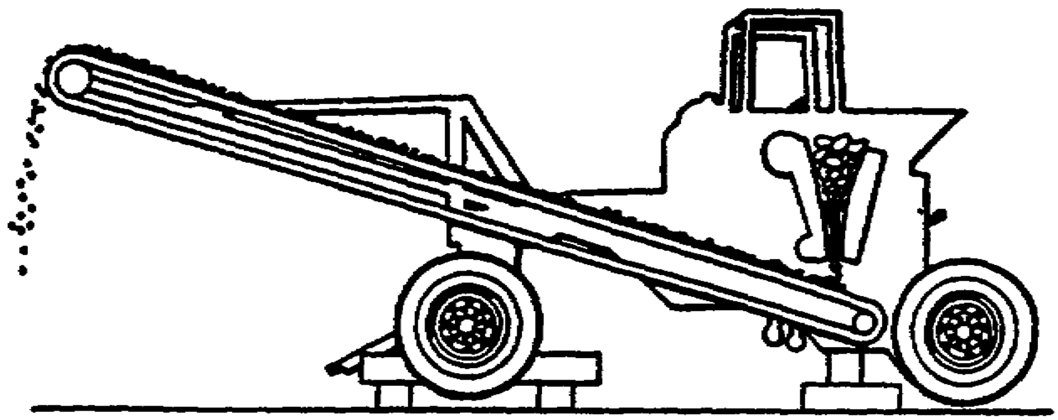
Learning Event 3
DESCRIBE MILITARY CRUSHING AND SCREENING PLANTS

Equipment is available in the military supply system to enable units to meet their own aggregate production requirements. The Army has a number of crushing plants of varying capacity (Table 1).

15-tph PLANT

Function and Operation. The 15-tons per hour (tph) plant is the smallest and the most simple of the crushing units (Figure 8). It is a small air transportable and air droppable jaw crusher. It is normally used by Engineer Airborne Units to support combat activities in forward areas. Its sole function is to crush gravel or quarry rock to product sizes suitable for base course material or limited concrete construction. The unit consists of a jaw crusher assembly, a delivery conveyor, a gasoline engine, and a rubber tired running gear.

FIGURE 8. 15-tph PLANT



Production Considerations. The 15-tph plant is capable of primary crushing only. It will receive raw material up to approximately 12 x 22 inches in size. The *maximum product* setting is 3 inches and the *minimum* is 1 inch. It will produce in the range of 15 to 45 tons per hour depending upon the toughness of the rock and the product setting.

Due to the inflexible nature and limited capability of the equipment, and the circumstances under which it is normally used, only the most basic concepts of utilization and employment apply. Because it is readily transportable, the

TABLE 1. PHYSICAL CHARACTERISTICS OF CRUSHING, SCREENING, AND WASHING PLANTS

Unit trailer mtd	Movement characteristics				Basic components					Attached accessory equipment				
	Weight (lb)	Height (traveling)	Length (traveling)	Width (traveling)	Jaw crusher size (in)	Roller crusher size and type (in)	Type screen	No. of decks	Type feeder	Sand dehydrator	Companion bin unit	Scrubber or washer	Attached conveyors	Elevating wheel
15 tph crusher	16,000	7'8"	18'8"	6'8"	14 x 24	—	—	—	—	—	—	—	1	
35 tph crushing and screening plant;														
Primary unit	45,000	10'6"	31'	8'	15 x 24	—	—	—	reciprocating.	—	—	—	1	
Secondary unit	48,900	10'6"	34'	8'	—	dual roll 24 x 16.	horizontal.	1-1/2	—	—	—	—	4	
75 tph crushing and screening plant:	—	—	—	—	20 x 36									
Primary unit	71,400	11'11"	44'	8'	—	—	vibrating grizzly.	—	apron	—	—	—	1	
Secondary unit	59,500	11'11"	45'	9'10"	—	dual roll 30 x 24	inclined	2	reciprocating.	—	—	—	2	x
75 tph washing and screening plant:														
Washing and screening unit.	41,200	14'21/8"	34'	8'11" 1/8"	—	—	horizontal.	3	—	x	—	x		
Screening unit	27,320	13'9"	46' 1 3/8	8'11 1/8"	—	—	inclined	3	reciprocating.					
225 tph crushing and screening plant:														
Primary unit	72,120	13'5"	36'2"	9'10"	30 x 42	—	grizzly	—	apron	—	—	—	1	
Intermediate (54 VDE).	75,640	13'2"	43'4"	10'	—	dual roll 54 x 24.	inclined	3-1/2	reciprocating.	—	—	—	3	
Crushing, screening, and washing (300 WDE).	64,480	14'1"	46'8"	10'2"	—	dual roll 40 x 22.	revolving and horizontal.	2	—	—	—	—	2	

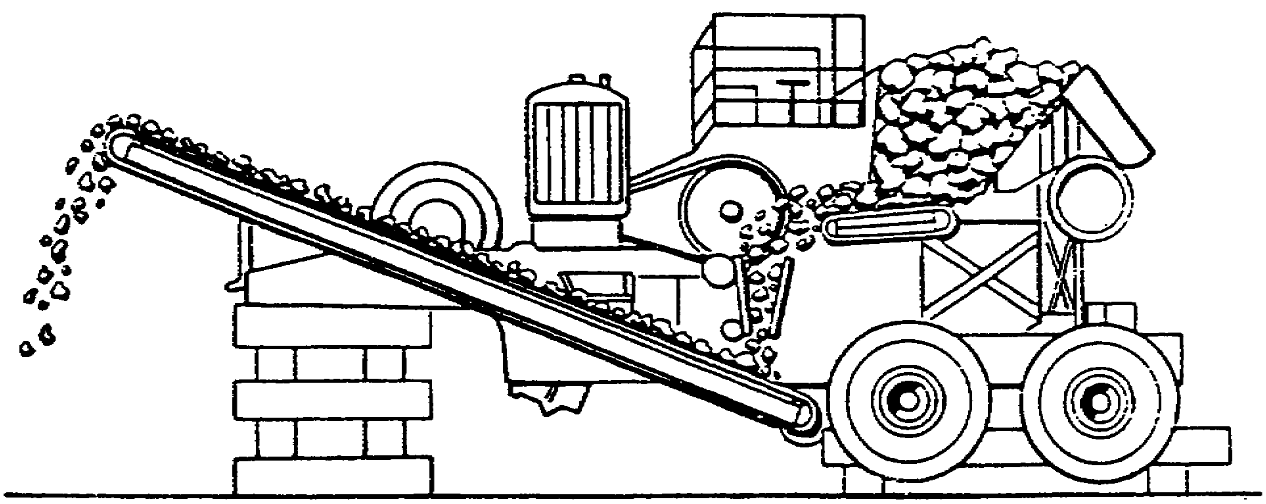
crusher is set up at the source of material to be crushed. It is important that it be jacked up or cribbed so that the rubber tires are off the ground, and level. It may be fed by some combination of headwall, chutes, and small materials handling equipment. However, in many circumstances, feeding by hand labor will prove to be the most practical method.

35-tph CRUSHING AND SCREENING PLANT

Function and Operation. The 35-tph plant consists of two relatively small, self-contained units. It is intended primarily to produce material needed to support light construction, maintenance, and repair projects of combat battalions.

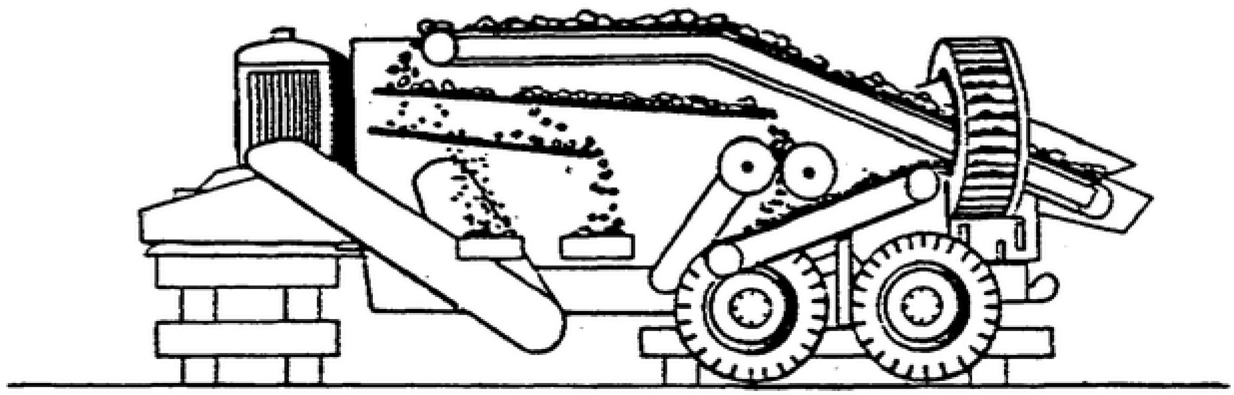
- The primary unit is used for initial reduction of quarry run rock and gravel (Figure 9). It is ideally suited to processing gravel pit source rock. Due to the relatively small jaw cavity opening (15 x24 inches) it is very difficult to reduce material to the ideal feed size by blasting in the quarry. The product of the primary crusher is suitable for base course material without further processing.

FIGURE 9. MATERIAL FLOW THROUGH THE PRIMARY UNIT OF A 35-tph CRUSHING AND SCREENING PLANT



- The secondary unit is used to accept the product of the primary crusher. It accomplishes necessary further reduction in particle size and screens the material into size ranges to meet specifications (Figure 10).

FIGURE 10. MATERIAL FLOW THROUGH THE SECONDARY UNIT OF A 35-tph CRUSHING AND SCREENING PLANT



The secondary unit is not capable of being used as a primary unit in gravel pit operations unless some field expedient is employed to prescreen the material to control the top size being fed into the machine, and to control the rate of flow.

Crushed rock product from the jaw crusher is discharged into the feed hopper of the secondary unit. Material that was crushed to product size in the jaw chamber will pass the top screen. The material that is oversize to the top screen is retained and directed through the dual roll crusher. It is further reduced in size and discharged onto the under crusher conveyor. It is then carried to and deposited into the revolving elevator wheel which picks it up and drops it back on to the over crusher conveyor which routes it back to the top screen. If any of this material is still too large, it will be sent through the roller crusher again. This is known as a *"closed circuit"* crushing system. *The product setting of the roller crusher must be equal to or somewhat less than the top screen opening size.* The material retained on the bottom screen represents the product size range. It is directed into a chute to a side delivery conveyor which carries it to the product stockpile. The product will contain the various particle sizes ranging between the top screen opening size and the bottom screen opening size. The material that is small enough to pass the bottom screen will be carried to the by-product stockpile.

Production Considerations. The jaw crusher can be expected to produce anywhere between 20 and 90 tons per hour. The actual rate depends primarily upon the toughness of the raw material and the size of the finished product. The *minimum* product setting is 1-1/2 inches and the *maximum* product setting is 4-1/2 inches.

Lesson 1/Leaning Event 3

The type of material being processed and the finished product size both have a substantial influence upon the hourly production rate of the secondary unit. The actual rate of production may be limited to the capacity of the top screen, the capacity of the bottom screen, or in some cases upon the crushing capacity of the dual roll crusher.

Graded aggregate is normally obtained by processing raw material through both units of the plant. Frequently it is most feasible to use only the primary unit to make base course material. In this case the fines are usually needed for binder and therefore screening is not required.

75-tph CRUSHING AND SCREEN PLANT

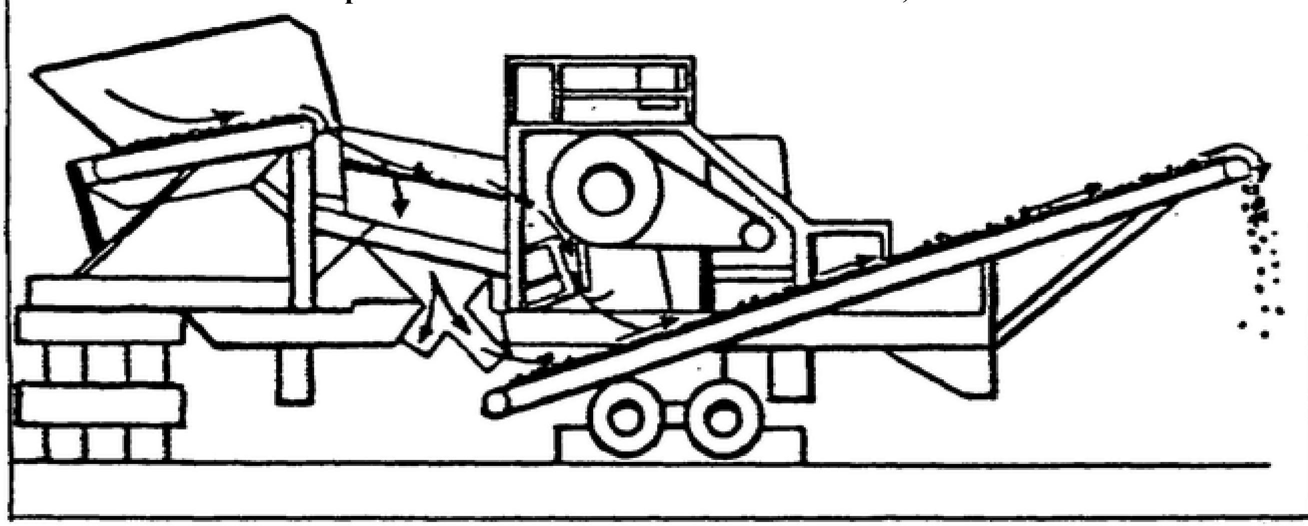
The 75-tph plant is a medium to large plant with substantial processing capability. It is primarily used to support construction activities of Engineer Battalions. It is subdivided into two separate and distinct sets of equipment. These sets are described below.

75-tph Plant, Set No. 1

Function and Operation. This set consists of primary and secondary units.

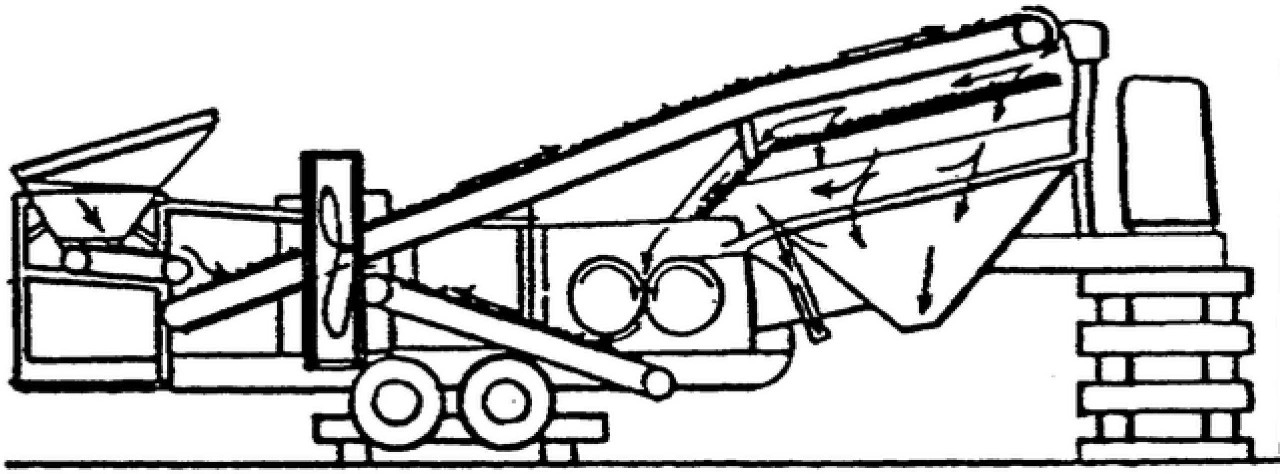
The primary unit (Figure 11) is used to accomplish the first stage of reduction of quarry run rock. It is also frequently used to crush coarse gravel. When used by itself, the product is suitable for base course material only.

FIGURE 11. MATERIAL FLOW THROUGH THE PRIMARY UNIT OF A 75-tph CRUSHING AND SCREENING PLANT, SET NO. 1



The secondary unit (Figure 12) is ordinarily used to process the product of the jaw crusher. Any further size reduction required is accomplished in the dual roller crusher, and the crushed stone is separated into product size ranges as required by specifications. The secondary unit of Set No. 1 has special features which also make it ideally suited to use all by itself in gravel deposits. The 75-tph plant uses a "closed circuit" crushing system, as does the 35-tph plant previously discussed.

FIGURE 12. MATERIAL FLOW THROUGH THE SECONDARY UNIT OF A 75-tph CRUSHING AND SCREENING PLANT, SET NO. 1



Production Considerations. The jaw crusher will produce in the range of 55 to 185 tons per hour, depending upon the product setting and the toughness of the material being crushed. The *maximum* product setting is 5 inches and the *minimum* setting is 1-1/2 inches.

The secondary unit has a wide range of production capability. The actual rate of production in tons per hour is usually determined by the screening capacity of the screens being used, although in some cases the rate may be limited by the capacity of the dual roll crusher.

The use of components within Set No. 1 is entirely flexible. Equipment is selected, arranged, and set up in such a way as to transform the available raw material into a usable product in the most practical and effective manner.

Equipment, Set No. 2

Function and Operation. Equipment Set No. 2 is composed of a washing and screening unit and an auxiliary screening unit. It is high capacity equipment normally found in Engineer Construction Support Units. It is commonly

used to augment or supplement the crushing and screening efforts of construction battalions.

The washing and screening unit is used to wash, scrub, rinse and screen crushed stone. It also washes and classifies sand. The auxiliary screening unit is a relatively simple three-deck screen. Its sole purpose is to separate aggregate particles into specific size ranges.

Production Considerations. The washing and screening unit is capable of producing up to three size ranges of graded aggregate and clean, processed sand. There is a wide variation in hourly production rates. This is dependent to a considerable extent upon the particle shapes and even more upon the size of screen openings installed. Rounded particles will process through screens faster than angular particles and large-sized screen openings will process material faster than smaller ones. The rate of production of the auxiliary screening unit is also determined by particle shape and size of screen openings.

This equipment is so highly versatile and is commonly used in so many different arrangements that no particular employment concept could be termed typical. It can be used to reprocess materials existing in stockpiles, to operate independently in gravel pit deposits, or in conjunction with the 75-tph Set No. 1 to increase production rates and processing capabilities.

225-tph PLANT

Function and Operation. The 225-tph plant is a very large, portable plant with tremendous processing and production capabilities. It is designed to process quarry rock or gravel in either washing or dry operations. It is issued on an as needed basis for large crushing and processing operations, and comes complete with the personnel necessary to operate it. The 225-tph plant is composed of a primary unit, a first intermediate unit, a washing plant, a second intermediate unit, and some other smaller items of equipment.

- The primary unit (Figure 13) is used to accomplish the first stage of reduction of quarry run rock. The primary unit is so large that it would not be practical to use it in gravel deposits.

- The first intermediate unit (Figure 14) is used to receive material from the jaw crusher and accomplish a second stage of reduction. It can also be used very effectively as a primary or first stage of reduction unit in gravel deposits. It may be used to produce a finished product and to reject fines.

FIGURE 13. MATERIAL FLOW THROUGH THE PRIMARY CRUSHER UNIT OF A 225-tph CRUSHING AND SCREENING PLANT

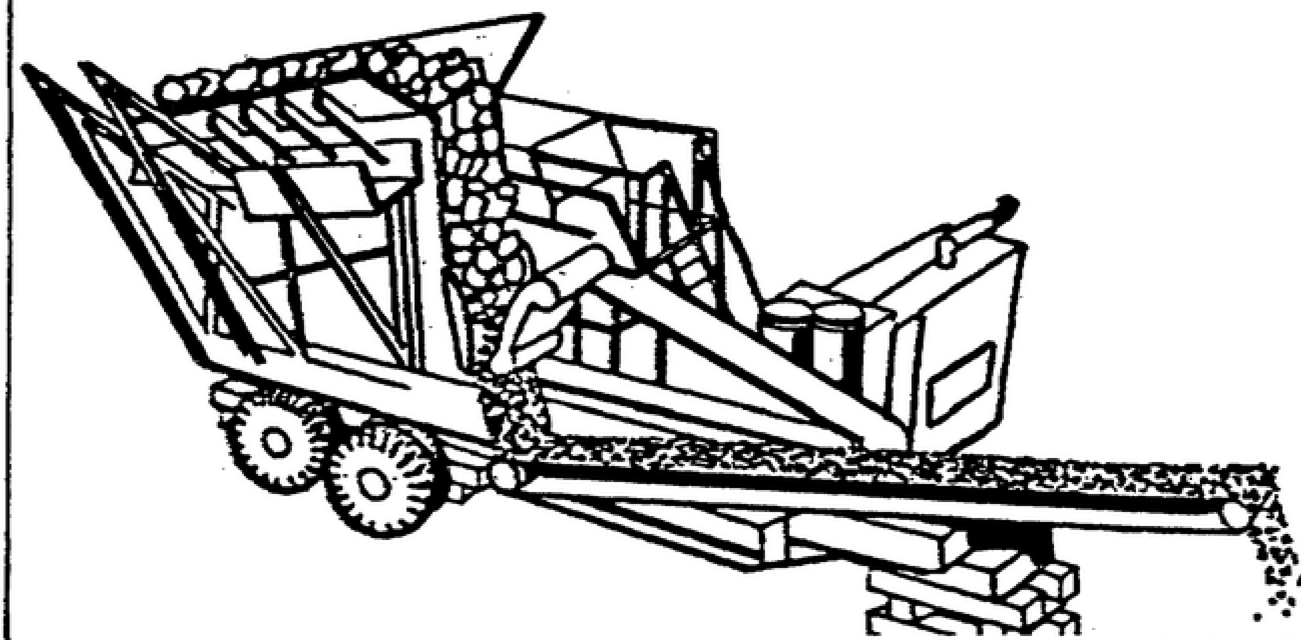
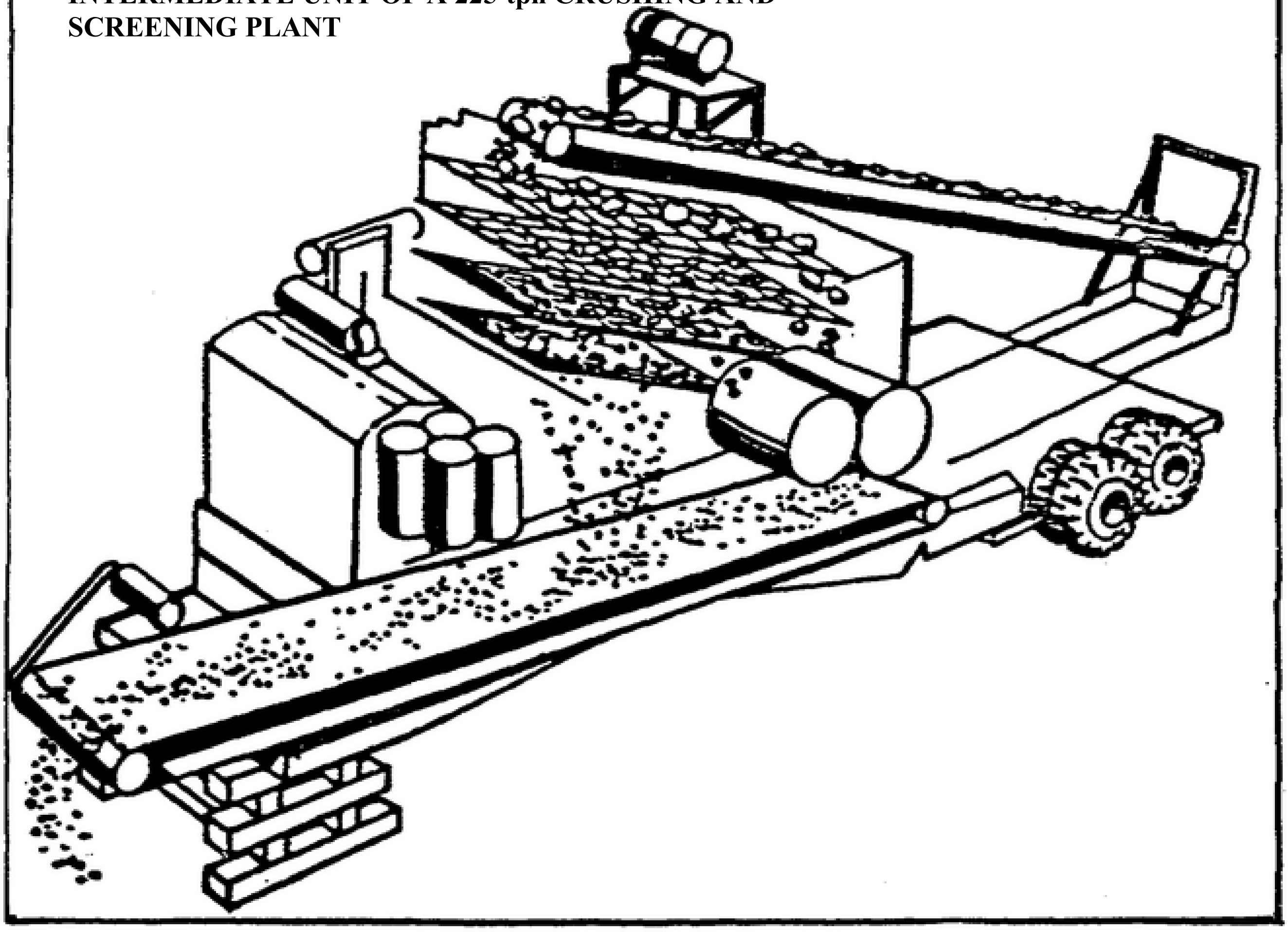
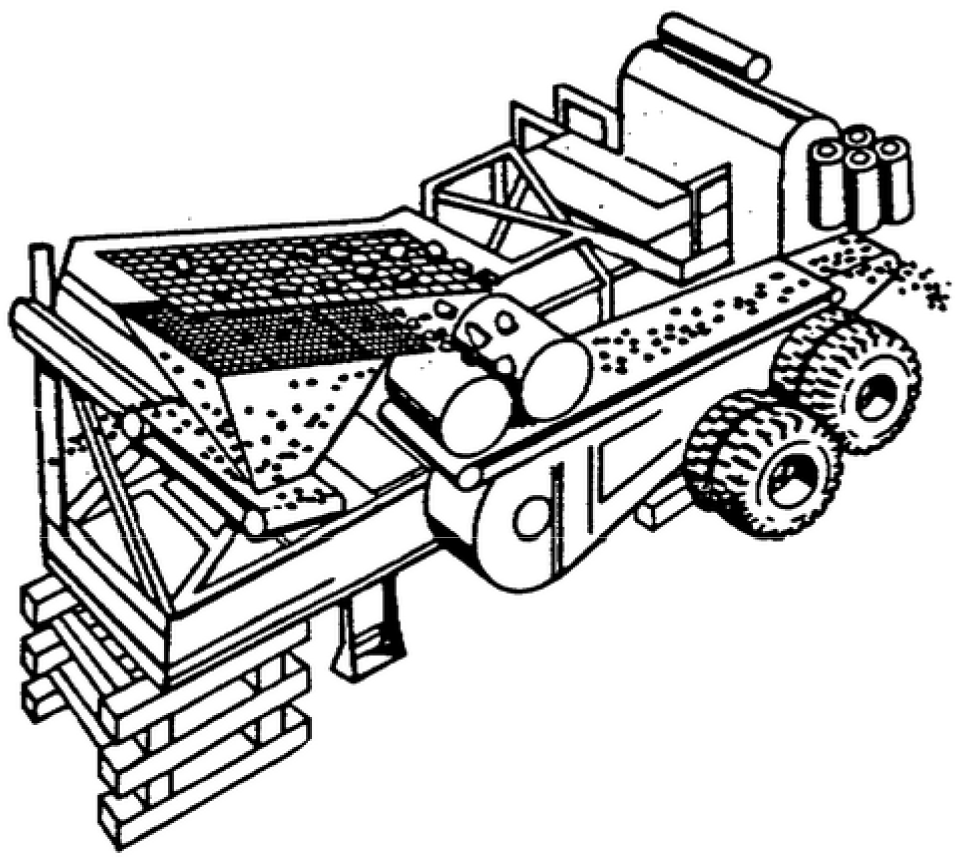


FIGURE 14. MATERIAL FLOW THROUGH THE FIRST INTERMEDIATE UNIT OF A 225-tph CRUSHING AND SCREENING PLANT



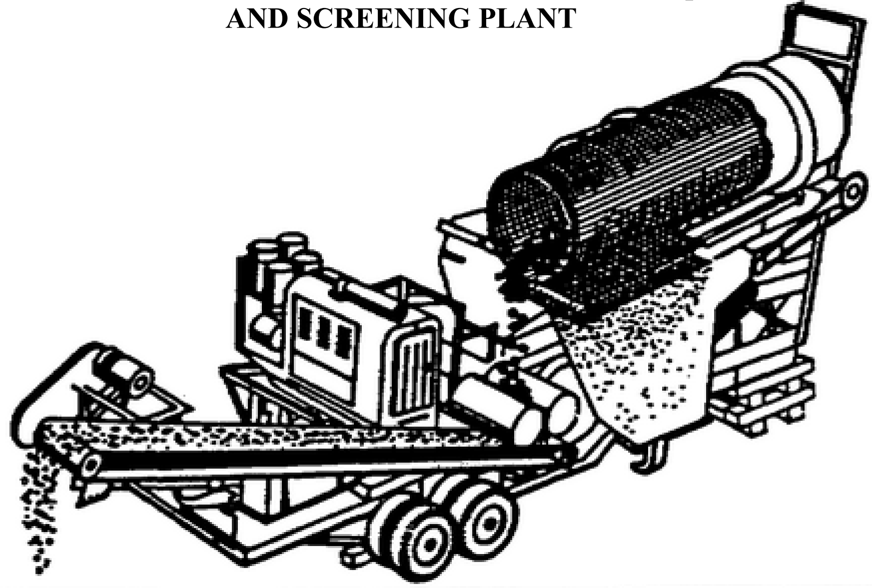
- The washing unit (Figure 15) receives material from the first intermediate unit, washes it, claims product size aggregates, and accomplishes a third stage of reduction to oversize particles. It also washes and classifies sand.

FIGURE 15. MATERIAL FLOW THROUGH THE CRUSHING, SCREENING, AND WASHING UNIT OF A 225-tph CRUSHING AND SCREENING PLANT



- The second intermediate unit (Figure 16) is a special crushing and screening unit normally used in the washing plant return system. It is used to increase production of fines (or sand) by taking material from the roll crusher, and from the bottom deck screen of the washing plant, reducing it to the sand size, and returning it to the feeder system of the washing unit. It is used either as a wet or dry operation.

FIGURE 16. MATERIAL FLOW THROUGH THE SECOND INTERMEDIATE UNIT OF A 225-tph CRUSHING AND SCREENING PLANT



- In addition to the major items described above, the 225-tph plant includes other items of equipment which have been explained in detail earlier in this lesson. This equipment includes a sand dehydrator, a log washer, a reciprocating plate feeder, and four conveyors.

Production Considerations. The jaw crusher, or primary unit, will produce between 200 and 400 tons per hour, depending upon the product setting and the toughness of the material being crushed. The *maximum* product setting is 8 inches and the *minimum* setting is 4 inches.

The first intermediate unit is capable of receiving gravel deposit materials or crushed rock up to 7 inches in size and reducing it. The maximum product setting is 4 inches and the minimum setting is 1-1/2 inches. This unit has a wide range of production capability. The actual rate of production is normally determined by screening capacity of the size screens being used, although in some cases the rate may be limited to the reduction capacity of the dual rolls.

The washing plant is capable of receiving gravel source material or crushed rock up to 4 inches in size, accomplishing further size reduction, and producing up to two size ranges of washed aggregate and clean, washed sand. It has a wide range of output production rates depending upon the screen sizes being used and upon the roll crusher product setting.

The second intermediate unit is capable of accomplishing a fourth stage of rock size reduction, and will produce up to one size range of crushed stone product and sand. It has a wide range of output production rates depending

upon screen size being used, roll crusher product setting, and whether the material is being processed wet or dry.

Overall, the 225-tph plant has a tremendous production capacity and processing capability when designed, laid out, erected, and calibrated properly. The manner in which it is employed is dependent upon the nature of the raw material available and the mission to be accomplished.

The 225-tph plant is most typically employed using four separate and distinct stage of reduction. The primary unit feeds the first intermediate unit, the washing unit is next in line, and then the second intermediate unit is used to further process some of the product of the washing unit.

The 225-tph plant equipment is highly flexible in its employment and use. This plant has a wide range of calibration possibilities. In addition to the layout described above, it can be arranged in numerous different ways to operate most effectively. The components selected and their employment depend on the characteristics of the raw material and the nature of the final product needed.

Learning Event 4
IDENTIFY SITE SELECTION FACTORS

INTRODUCTION

You should develop a well-planned layout and design of your quarry crusher plant to maximize production. In this Learning Event you will learn to select a site, plan the layout of the crusher complex, erect the plant, and evaluate its operation. Some management aspects of maintenance and personnel training will be discussed as they affect plant operation and production.

After the equipment has been selected for the facility, you must select a site for the installation. Special care should be devoted to this task in that your rock processing facility is a rather permanent installation. You should give thought to future operations and the amount of crushed rock that will be needed. These are basically the same considerations you use to choose the quarry site itself.

SECURITY

The most important factor you should consider in selecting a site is security. Most rock crushing plants, because of their location in wide open areas, present inviting targets for enemy harassment. Remember, these plants are in operation 24 hours per day. If they are not employed in secure areas, personnel will have to be made available to guard the installation.

DISTANCE FROM QUARRY

You should locate the rock crushing facility as close to the quarry as possible. The minimum distance will be governed by the rock throw of the quarry blast. By locating the plant close to the quarry, maximum utilization of haul units can be realized. This is important because the raw material brought to the crusher from the quarry contains both product and by-product material, while the material hauled to the construction project from the crushing plant is all product size material. If the crusher can be located sufficiently close to the quarry, dozers can be used to push the quarry run rock to the plant. Consider the development plan of the quarry so as not to locate the crushing plant in the path of future quarry faces.

TERRAIN

The terrain for the plant should be suitable in load carrying ability to support heavy equipment with only minor earthworking improvements. It should be sloping to provide good natural drainage. Proper utilization of a hillside or sloping location may allow you to use gravity as an aid in moving material from a rock face to the crusher, from the crusher to a storage area, or from a storage area to the haul units. A hillside location also simplifies drainage problems, particularly when washing operations are undertaken.

SPACE

The area required for your plant will depend on the processes through which the material must pass and the equipment selected to perform the processes. You must provide space for operation of the equipment to be used in moving the material to the crusher, for loading or feeding the crusher, for a surge pile, if necessary, to assure continuous plant operations, and for stockpiling the finished product. You must also provide space for the storage of various operating and maintenance supplies, and for the operation of the equipment used to outload the final product. Only the units needed to produce the desired material should be used since an unneeded unit may cause lower production as well as extra maintenance. However, space for future development of the plant must be considered since it often happens that the plant as originally designed must be enlarged from time to time.

ACCESS AND HAUL ROADS

Haul roads should be as short as possible and capable of handling the loads expected to be imposed upon them. Two-way roads to and from the operational area are usually adequate. However, a loop road for one-way traffic is essential within the operational area so that routes of empty and loaded trucks do not cross.

WATER

When aggregate washing operations are being planned, *you can determine the approximate number of gallons of water per minute which must be provided by multiplying the number of tons of aggregate produced per hour by 10*. The problem of providing and disposing of water may be alleviated by the use of a settling basin. These settling basins prevent contaminated water from running directly into streams and also permit the reuse of water for washing operations.

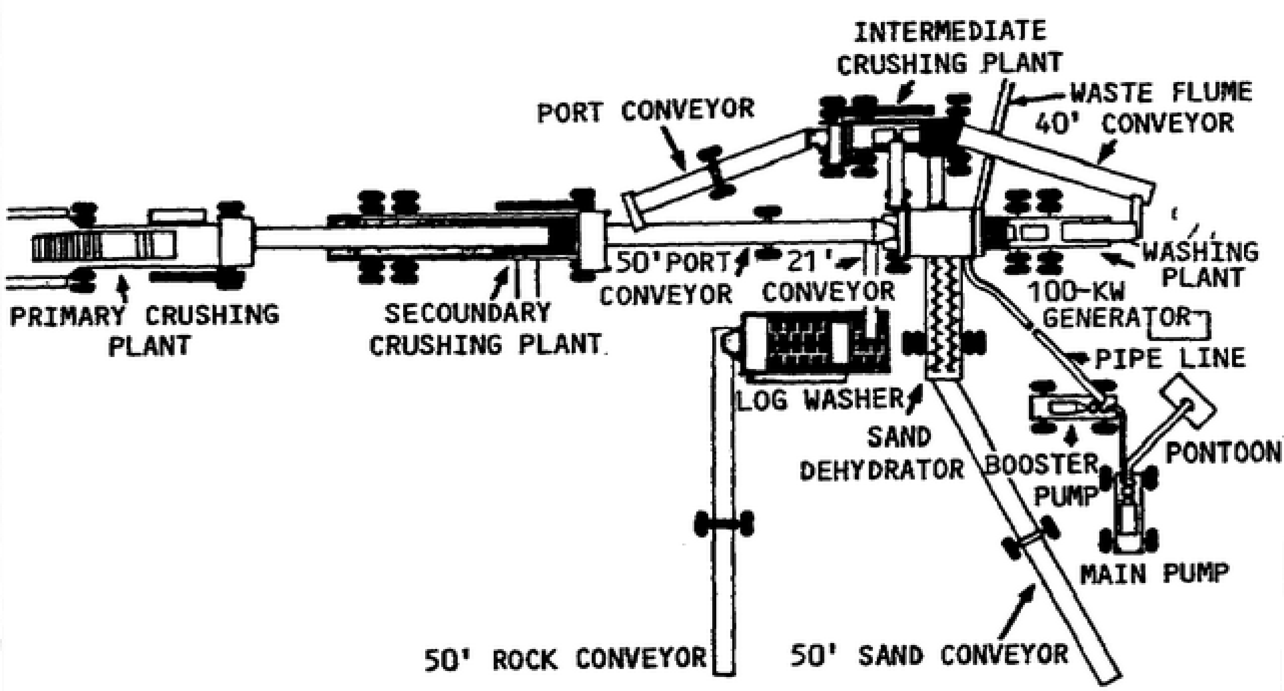
UTILITIES

Where possible, you should make maximum use of existing utilities. Commercial electrical power can be used to operate the electrical components of the crushing equipment. Although the electric motors in the plant are designed to operate on 60 cycle power, they can be operated on 50 cycle power. This will decrease the efficiency of the plant and is not recommended for sustained operations, but for short term operations it can be applicable.

Learning Event 5
DESCRIBE A PLANT LAYOUT

The actual layout and erection of the plant are the final tasks in the plant design and layout process. You should give adequate time to this effort in order to build an efficient facility. Figure 17 illustrates a typical crushing and screening plant arrangement. Once the plant is in operation, there is seldom any time to stop operations and remodel. The following factors should be considered during this critical time. Again, these considerations are basically the same as those you use to layout the quarry site.

FIGURE 17. A TYPICAL ROCK CRUSHING AND SCREENING PLANT LAYOUT



EQUIPMENT CONFIGURATION

Plans should be initially solidified for the equipment configuration within the plant. You should give special attention to creating a productive, logical flow of material from the point where the trucks enter the plant with raw material to the point where the trucks leave the plant with crushed aggregate product. You should evaluate the physical environmental requirements of each piece of equipment, such a foundation requirements, water requirements, and power requirements, to ensure that they are included *during the construction stage.*

DRAINAGE

Drainage is of prime importance in constructing the facility. You should construct adequate drainage channels during the initial earthworking stage of construction and constantly improve them as the plant is built. This is most significant in that most of the rock crushing plants have electrical components inherent to their operation.

PREVAILING WINDS

You should orient equipment in such a manner that prevailing winds carry the rock dust generated by the processing machines *away from the facility*. You should take care to locate supporting equipment such as generators and water pumps and permanent facilities, such as latrine, office, and maintenance shops *out of the path of winds* carrying the rock dust.

ORGANIZATION OF SPACE

Your plant design should include adequate space around the equipment. This is needed to provide access areas for maintenance personnel to perform repairs on the equipment, space to move cranes in to lift out and replace worn jaw plates and roll shells, space for fuel trucks to move in and fuel the equipment, and space to remove and replace complete processing units.

MATERIALS HANDLING AND STORAGE

Your plans for the plant should include adequate materials handling devices to expedite the flow of material through the plant and eliminate double handling of the material.

You should use gravity flow through chutes where possible to eliminate the need for haul units. A headwall-ramp should be constructed to allow haul units to back up to the apron feeder of the primary unit and discharge their loads. If a problem with oversize rock is anticipated you should have a prescreening grizzly built in the quarry or over the apron feeder to remove the oversize rock.

When possible, you should store quality product size aggregate in bins rather than in open stockpiles. This is most important when the aggregate is crushed to specification sizes or has been washed. Open stockpiling of aggregate can cause contamination of the product by windblown sand, fines, and trash. Also the use of bins allows the complete use of all the product that is produced. Trucks drive under the bins and load the vehicles through trap doors in the bottoms of the bins.

If the bins are not available for aggregate storage, headwalls should be built for stockpiles to ensure separation of the different sizes of aggregate being processed. The area separating headwalls should be large enough to stockpile

a large supply of aggregate and have adequate space on the front side for loading vehicles without causing congested traffic areas.

Aggregates stored in stockpiles will be loaded by scooploaders or clamshells. These machines are most efficient for loading vehicles with clean aggregate off the top of the stockpiles. Near the bottom of the stockpile, the product becomes embedded in the ground and tends to be contaminated. This layer is then lost for use.

When you use conveyors to build stockpiles of aggregate, remember that the conveyor can be elevated between 12° and 20°. *Adjust the elevation of the conveyor so that the rock product does not drop over 3 to 5 feet.* Also, the wheels on the conveyors can be rotated 90°, thereby enabling you to build radial stockpiles with little equipment repositioning effort.

OTHER FACILITIES

If yours is a long term operation, you will need to plan for permanent facilities and structures at the crusher site. The buildings and facilities you will need include office space for the production records, a building for spare parts and maintenance tools, storage, and an area for POL storage, parking, and latrine facilities. If aggregate must be washed, you will need to provide water from a stream or well. Another special consideration is for a lighting system if the plant is to be in operation after dark.

ROAD NETWORKS

All through the plant erection stages you should make plans for the road networks within the plant. These well planned roads are needed to prevent congestion, decrease the time haul units are in the plant, and for safety. The following three road networks are needed for:

- haul units bringing rock from the quarry,
- trucks hauling the product aggregate to construction sites, and
- service vehicles such as jeeps, 3/4-ton trucks, maintenance trucks, etc.

The plant roads should be one way where possible. You should construct them wide enough for the largest haul unit expected and design them to support heavy loads. These roads should be maintained constantly. In dry areas where there is little rainfall, a water truck should be used to wet down the roads to eliminate dust. In wet areas crushed rock should be placed on the roads to keep haul units from sliding off into ditches. A maximum speed limit should be posted for vehicular traffic within the plant and on the haul roads.

Learning Event 6
DESCRIBE SITE PREPARATION AND PLANT ERECTION

CRUSHER PLANT SITE PREPARATION

Your site preparation for the crusher plant will consist of the following basic steps:

Preliminary Earthwork. Initially you should cut the lower level of the site to grade and proper dimensions. A predetermined portion of the material may be deposited above the hardstand for later use in backfilling behind the retaining wall. You may do the excavation for the hardstand simultaneously.

Hardstands. Hardstands must be constructed to support the equipment. This is due to the weight of the equipment and settling that could be caused by the constant vibration of the machines as they process the rock. Ideally a concrete pad would be desired as a hardstand, but this is seldom possible in the field. You can use a primary crusher to produce base course material to provide material for a hardstand. This material should be leveled and well compacted to provide adequate support.

Retaining and Wing Wall Construction. Following completion of the earthwork on the lower level, you may start work on the retaining walls. Support for the retaining walls may be provided by driven piles. Holes may be drilled and piles set in and concreted individually, or the base of the wall may be entrenched and piles set in a continuous concrete footer.

ERECTING THE PLANT

The importance of proper site preparation and proper stationing of the plant cannot be overemphasized. Your site for stationing the plant should be flat, level, and well compacted. Crushing and screening plants may be operated for short periods of time from the wheelbase. But it is advantageous on longer and more deliberate jobs, from a maintenance standpoint, not to operate the plant until it has been blocked and leveled with the tires clear of the ground.

You should include the following steps in the blocking, leveling, and operational startup phases.

Leveling. You should level the plant both transversely and longitudinally before initial operation. This should be frequently checked while the plant is in operation. Leveling should be done on the unit frame, and a rigid, straight plank should be used across the unit frame rails for transverse leveling. The level should be checked at several points throughout the unit.

Blocking. You should install blocking under each side of the tandem axles and under the dolly axle to raise the tires clear of the ground. Place blocking parallel to the longitudinal centerline of the unit. If cribbing is used, the ground timbers should be parallel to the longitudinal centerline of the unit.

Hydraulic Jacks. Always use two hydraulic jacks. One should be on each side of the unit opposite each other and under the unit frame members. Raise and lower the jacks in equal increments to prevent bending of the frame.

Screw Type Stabilizing Jacks. After you have blocked the unit level, the screw type stabilizing jacks should be tightened to maximum torque.

Retorquing of Nuts and Bolts. You should ensure that all bolts are tightened by torquing the nuts, not the bolt heads. You should continually retorque throughout the operation of the plant. This should be done especially at critical points and during the initial operation to assure proper seating and to prevent parts from loosening and getting out of adjustment. Any adjustments required, such as movement of trunnion wheels on the trunnion shaft, should be made during the first hours of operation.

Jaw plates and roll shells are held in place by wedges which are secured by keeper bolts. The wedges must be driven "home" with a sledge hammer while constantly applying torque with the wrench to achieve proper tightening.

Visual Inspection. You should visually inspect the plant continuously from ground level and from the platform and walkways to promptly detect any misadjustment or loss of adjustment to prevent damage and eventual breakage.

Adjustments. You should make and check all adjustments with the components operating while empty and recheck while loaded with aggregate.

Operating Instructions. You should refer to the appropriate technical manual for complete operating instructions.

Training. You should train all personnel assigned to operate the plant. During this training period the importance of site preparation, set-up, maintenance, and safety should be emphasized. You should keep the proper tools, materials, and manuals at the site. A high rate of aggregate production should not be expected until personnel become familiar with the equipment.

Tools. Military crushing and screening plants are of necessity more compact than equivalent commercial plants. This is because they must be transportable by highway, rail, or air. This compactness reduce clearances at many vital maintenance points which, together with the high torque required on most nuts and bolts, makes high quality proper tools an absolute necessity. The use of proper tools will also reduce maintenance time as less disassembly will be required. The tools used in maintenance and assembly of the plant are included in the mechanic's tool set which is TOE to the organization, and the basic issue items that are incorporated with each plant.

Maintenance. Equipment maintenance has a direct effect upon equipment operation. In order to accomplish a construction mission in the minimum possible time, your construction unit must have and maintain a high state of maintenance. Improper organizational maintenance is the cause of many equipment failures. These failures normally occur when the equipment is used the hardest or when it is needed the most. More operating time at the sacrifice of maintenance will result in lower overall production in the long run.

PRACTICE EXERCISE FOR LESSON 1

Instructions

Check your understanding of Lesson 1 by completing the practice exercise. There is only one correct answer to each question. Try to answer all of the questions without referring to the lesson materials.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand, before continuing to the next lesson.

1. What five factors must you evaluate in order to select the appropriate rock crushing equipment required for a job?

   ____

   ____

   ____

   ____

   ____

2. What does the mission dictate to you about product requirement? List the two ways product sizes may be specified.

   ____

   ____

3. What is meant by "stage of reduction" in crushing operations?

   ____

   ____

4. Your operators have made every crusher adjustment and screen size selection possible. But you are still getting too large a proportion of smaller sized particles (fines). What else can you do?

   ____

5. Which crushing plant(s) would you mot likely choose to support the construction mission of a construction battalion?

____

6. Which *Set* of 75-tph plant equipment would you want for primary and secondary reduction purposes?

____

7. What four basic functions do crushing and screening plants accomplish?

____

____

____

____

8. Your crushing plant produces 96 tons of aggregate per hour. This aggregate will be used for concrete and must be washed. Estimate how much water per minute you will need to keep up with demand.

____

9. Give two reasons why you should plan the plant's layout carefully.

____

____

10. What three road networks should be built at a plant site?

____

____

____

11. What three basic steps should you include in the crusher plant's site preparation?

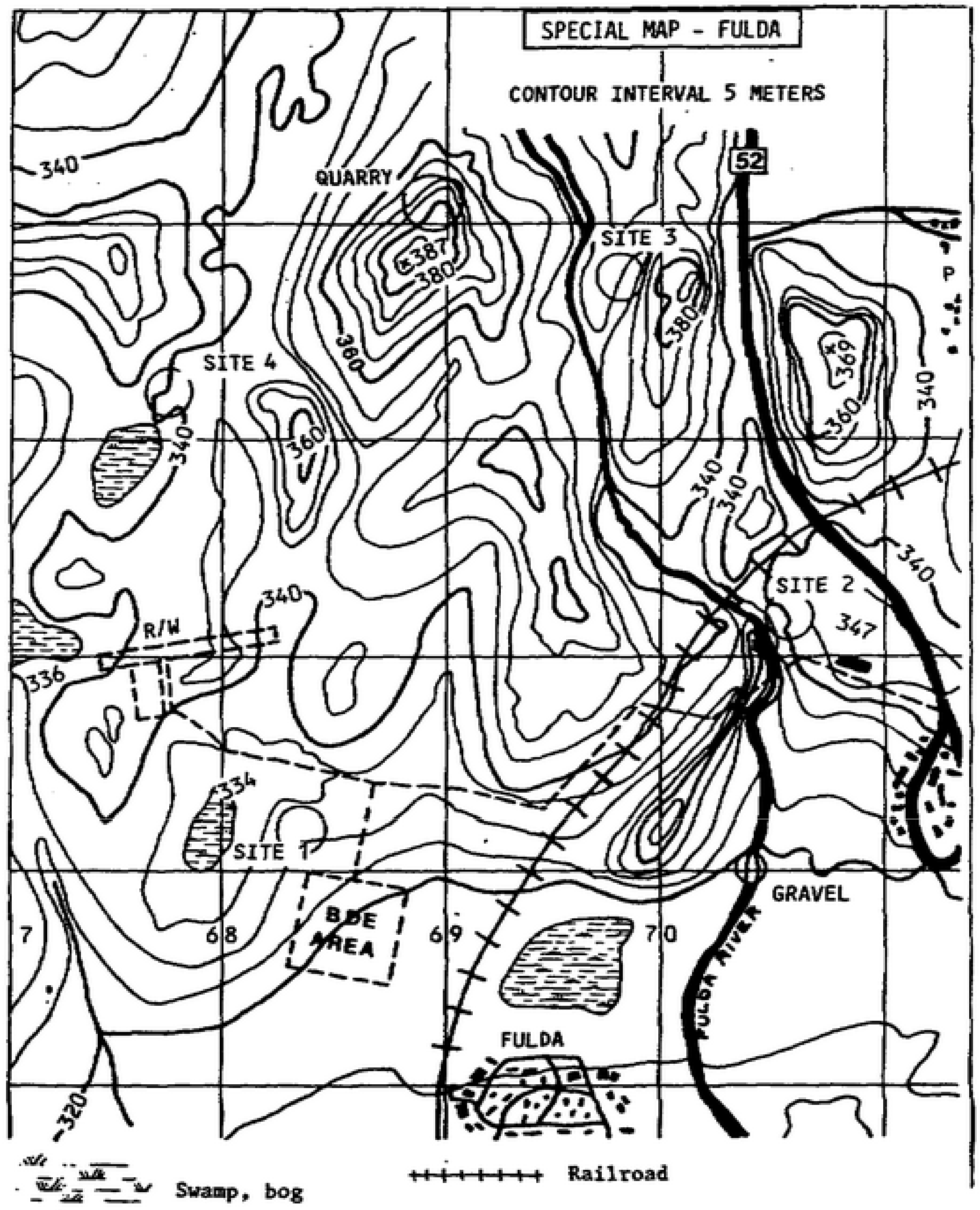
____

____

____

Use the information and map given below to answer questions 13 through 16.

Your Operations NCO has made an initial map reconnaissance of the area of operations. He has located four possible sites for the rock crusher complex. The quarry site and a source of river-run gravel are indicated. You are directed to plan for a future washing and screening operation.



12. It is preferable to operate your crusher plant after it has been _______________ and ________________ to minimize wear and tear.

13. What is the mot serious drawback with Site #1?

____

14. Give an example of the greatest asset and greatest liability of Site #2

____

____

15. List at least three advantages of Site #3.

____

____

____

16. List at let two advantages of Site #4.

____

____

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Lesson 1
ANSWER SHEET FOR PRACTICE EXERCISE

		Learning Event
1.	Mission, equipment available, raw material, processing required, and a flow chart of material through the facility	1
2.	The mission indicates the size and amount of rock product required and the time required to complete the job. The product size may be specified at a maximum top size or as graded product size.	1
3.	Stage of reduction is the difference in maximum input and maximum output size of material (expressed in inches or centimeters) due to a single crushing action.	2
4.	Damming and splitting may be used.	2
5.	75-tph plant	3
6.	Set No. 1	3
7.	Particle size reduction, separation of particles into size ranges, elimination of undesirable materials, movement of material from one place to another	2
8.	About 960 gallons of water per minute	4
9.	The plant's efficiency and productivity depend on a good plant layout. Once the plant starts operation, rearranging layout becomes extremely difficult and may be impossible since plants can seldom be shut down for this reason.	5
10.	A network for haul units to bring rock from the quarry; a network for trucks hauling product to construction sites; and a network for service vehicles	5
11.	Preliminary earthwork; hardstands; and retaining and wing wall construction	6
12.	Blocked and leveled	6

		Learning Event
13.	The distance to the quarry is the most serious drawback of Site #1.	4
14.	The greatest asset of Site #2 is the river which provides a good source of water. The greatest liability is the security risk of ready vehicular access to Site #2.	4
15.	The advantages of Site #3 are proximity to the quarry, adequate water availability and good drainage.	4
16.	The main disadvantages to Site #4 are the two hills overlooking the site and swampy terrain.	4

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LESSON 2

ESTIMATE PRODUCTION RATES FOR QUARRYING EQUIPMENT

OVERVIEW

LESSON DESCRIPTION:

This lesson addresses the procedures for calibrating rock crushing plants and estimating hourly production rates. Plant calibration and plant production estimation require a total of determine hourly production rates of your rock crushing equipment.

TERMINAL LEARNING OBJECTIVE

ACTION:	Demonstrate your ability to estimate the production rates for quarrying and rock crushing equipment.
CONDITION:	Given the material contained in this lesson, a No. 2 pencil, paper, and an ACCP Examination Response Sheet.
STANDARD:	Correctly answer all questions in the practice exercise at the end of this lesson.
REFERENCES:	The material contained in this lesson was derived from TM 5-331-C and TM 5-332.

INTRODUCTION

The following nine-step procedure is used to calibrate and estimate production for all Army plants:

Plant Calibration

1. Screen Selection
2. Roll Crusher Setting
3. Jaw Crusher

Plant Production

4. Jaw Crusher Capacity
5. Roll Crusher Capacity
6. Sieve Analysis
7. Graduation Check
8. Screen Capacity
9. Final Graduation Check

Learning Event 1
DESCRIBE PLANT MANAGEMENT CONSIDERATIONS

The purpose of this Learning Event is to give managers an overview of managerial aspects that should be kept in mind when utilizing rock crushing equipment.

ASSIGNMENT OF TASKS

Commanders should assign rock crushing tasks that are commensurate with unit capabilities. Many times additional rock crushing equipment is given to a unit that has its own TOE equipment, and some cases it is given to units that have no TOE rock processing equipment. In such instances, it is imperative that the additional personnel and maintenance support be provided these units to operate and maintain the equipment. In most cases, personnel will have to be trained on these machines. Adequate time should be allotted for such transitions.

COMMAND AND CONTROL

The reduction of rock at the quarry face is the first step in the construction process. The processing of rock through a crushing plant is the second step. Commanders should exercise a great deal of command interest and control of this activity. Following are some aspects of this control:

Adequate Lead Time. Commanders should allow adequate lead time for the crushing plant to be designed and erected. Once the plant is set up and put into operation, it is not likely that it will be shut down to make major improvements in the facilities. Commanders should also calculate the time that will be needed to crush advance stockpiles of aggregate for future construction operations. This is especially critical when planning asphalt and concrete paving operations. Remember that *support* equipment and personnel will be needed to build a plant of any size.

Maintenance of Equipment and Facilities. Commanders should inspect the maintenance of physical facilities such as haul roads, drainage structures, buildings, and maintenance areas. A lack of attention to these areas can cause future problems of such a magnitude that they will cause production delays.

Coordination. Commanders must coordinate operations between many parts of the quarry-rock crushing operations. To maximize production of crushed rock, the quarry must supply the raw material in sufficient amounts. The quarry personnel may have to construct a grizzly to remove oversize rock which the rock crushers cannot handle with their equipment. An exchange of ideas and techniques between quarry and crusher personnel will lead to improved utilization of equipment and increased production. Support unit such as maintenance companies should be prepared technically to diagnose

problems quickly in order to minimize downtime due to maintenance problems. *Blasting!* Blasting times must be established so personnel in the quarry and rock crushing area close to the blast can be evacuated before the blast. These are only a few of the areas to be coordinated by the commander. Experience and attention will reveal many others.

VARIABLE PRODUCTION RATES

Remember, you should not use the tonnage nomenclature of the rock crushing plant to estimate production rates. Three variables that influence production rates are the type of rock being crushed, the feed size of the raw material, and the size of the finished product desired. These variables are discussed below.

Type of Rock Being Crushed. The harder the rock is the longer it will take the crusher to reduce its size. For instance, it takes more time to crush basalt than limestone. Table 6 gives the production factors for various types of rock relative to limestone according to the hardness of the material.

Feed Size of Raw Material. Production will be increased as the feed size of the raw material is decreased. This is because it takes less time to crush the smaller rocks in the crushing components than the rocks that approach maximum feed size.

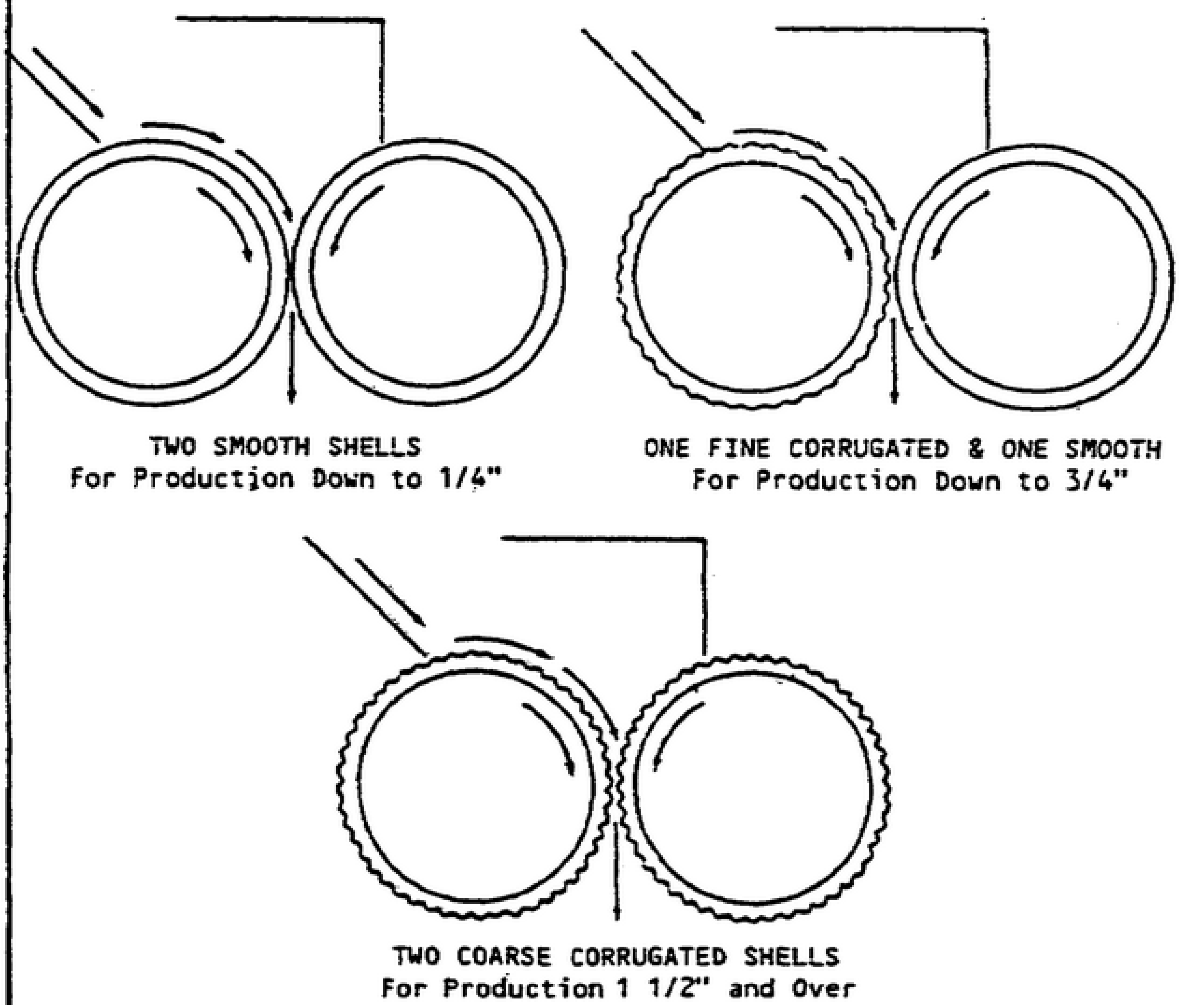
Size of Finished Product Desired. The size of the finished product is the most important factor to consider when determining production rates. It takes more time to crush rock down to 1-inch size than down to 2-inch size. It should be remembered that when the product must meet graded size specifications, production may be less than the tons per hour (tph) nomenclature of the plant. Although the plant may be able to process 80 tph of quarry rock, only 50 tph may be in the desired product range with the remaining 30 tph being too small to meet specifications. In some cases, the 30 tph of by-product may be of value in other construction operations, but for planning purposes when aggregate is crushed to graded size specifications there will be product and a by-product.

PRIORITIES

Priorities should be established as to what size aggregate will be produced and for which construction projects it will be produced. Where several projects are under way that require crushed rock, priorities must be established at a high level to insure that the crushed aggregate goes to the right job. Avoid changing specifications or desired product sizes where possible. For example, one battalion produces 1-inch minus and 1/2-inch minus for its construction projects, and another battalion of the group produces the same two sizes for its projects. It would be better to have one battalion produce all the 1-inch minus rock and the other battalion produce all the 1/2-inch minus rock. This

avoids down-time for recalibration of the plant to produce a second size product and aids in the management of stockpiles. This concept is most profitable when a plant must produce two sizes of product which cannot be processed without changing the roll shells of the secondary unit for the second size (Figure 18).

FIGURE 18. SHELL COMBINATIONS FOR DUAL ROLL CRUSHERS



For example, to produce 1-inch minus material with the 75-tph plant, a fine corrugated and smooth roll shell combination would be used in the secondary unit. But to produce 1/2-inch minus aggregate with the same plant, two smooth roll shells would be required in the secondary unit. To replace the

fine corrugated roll shell with a smooth corrugated roll shell in order to produce the 1/2-inch minus aggregate requires approximately four days' work. Thus, four days of production would be lost. In this case, if two plants were available, it would be better to run one plant producing 1-inch minus material and the other producing 1/2-inch minus material. If only one plant is available, you should assess long range need of each different size aggregate to eliminate as many changes in plant calibration as possible.

RECORDS

There are no formal printed records in the military for use in a rock crushing facility other than maintenance records. You should keep some records of your rock crushing operations. Some items that you should record are:

- amount of quarry rock delivered to the crushing plant per day,
- amount and size of the various product size aggregates produced each day,
- amount of product on hand,
- amount and size of product issued to various units for construction projects,
- down-time encountered each day, and
- calibrations for various size products.

EVALUATION

The evaluation of crushing activities is your responsibility. Although you may not possess a technical knowledge of all the aspects of crushing operations, there are at your disposal qualified personnel to provide advice. Such personnel trained in the application of crushing equipment should be consulted when you make evaluations.

Learning Event 2
CALIBRATING A ROCK CRUSHING PLANT

In planning for crushing and screening plant operations, there are two basic objectives. The first is the provision of the aggregate in the required size. The second is the provision of the aggregate in the required quantities. The first objective can be easily met through selection of screens which will separate the material into the sizes required. Achievement of the second objective involves not only the selection of the proper equipment but proper adjustment of the equipment as well. This Learning Event will outline the steps for selecting screens for the crushing plant and adjusting the crushing equipment for maximum efficiency.

SCREEN SELECTION

Before any adjustment can be made to a crushing and screening plant, it is necessary that the desired gradation of material to be processed be obtained from appropriate specification. Once the gradation has been determined, screens must be selected that will segregate the materials into appropriate sizes. The number of screens to be selected is dependent upon the number of size ranges into which the material must be segregated and the type of equipment available for screening. Table 2 gives the screen sizes of vibrating screens which will produce specific sizes of aggregate.

EXAMPLES OF SCREEN SELECTIONS

The selection of screen sizes is dependent on the size product desired. The maximum and minimum sizes of the product are expressed in the specifications. For example, consider the following specifications:

Size	Percent Passing
1-inch	100 percent
3/4-inch	90-100 percent
1/2-inch	20-50 percent
3/8-inch	0-15 percent
#4	0-5 percent

By this specification the largest size aggregate that is acceptable is 1 inch. Since 100 percent must pass through the screen for 1-inch aggregate, 0 percent can be larger than 1 inch. Although the specification says that the lot is acceptable with up to 5 percent of the total product passing through a #4 sieve, it is generally understood that the #4 aggregate is the smallest size desired.

Based on these specifications the plant should be calibrated to produce a product between 3/4 and 3/8 inch. The reasoning behind calibrating the plant to produce a 3/4-inch to 3/8-inch aggregate rather than a 1-inch to #4 size

aggregate is because somewhat oversize particles can pass a given screen opening size when oriented diagonally.

By calibrating the plant to produce a top size of 3/4-inch aggregate, a safety margin of 10 percent is provided in the event the product stockpile may contain aggregates over 3/4 inch but less than 1 inch. The same reasoning holds true on the minimum product size. Calibrate the plant to produce 3/8-inch aggregate as the minimum size, thereby creating in this case, a 15 percent leeway for particles in the stockpile being less than 3/8 inch. Therefore, *you should choose the next smaller se screen than the given maximum specification size for the upper size calibration. Similarly, you should choose the next larger size screen than the given minimum specification size for the lower size calibration.*

However, it is necessary to select screens *with openings slightly larger than the size products desired*, due to screen inefficiency caused by the angle of inclination, throw, and angular particle shapes. Table 2 is used for the selection of screens. This table shows the relationship between product size and screen size.

TABLE 2. VIBRATING SCREEN SELECTION CHART

Product size	*Required screen size*
No. 8	No. 4
No. 6	3/16"
No. 4	1/4"
1/4"	5/16"
5/16"	3/8"
3/8"	7/16"
7/16"	1/2"
1/2"	5/8"
11/16"	3/4"
3/4"	7/8"
7/8"	1"
1"	1-1/8"
1-1/8"	1-1/4"
1-1/4"	1-3/8"
1-3/8"	1-1/2"
1-1/2"	1-3/4"
1-3/4"	2"
2"	2-1/4"
2-1/4"	2-1/2"
2-1/2"	2-3/4"
2-3/4"	3"
3"	3-1/2"
3-1/2"	4"

Lesson 2/Learning Event 2

Assume that your plant has a two-deck, vibrating screen. In this case the following screens would be selected:

Product Size Desired	Screen Size Selected
Top 3/4-inch	7/8-inch
Bottom 3/8-inch	7/16-inch.

Note the relationship between aggregate size and screen size. The required screen sizes are slightly larger than the product sizes. If a 7/8-inch screen is not available, a 3/4-inch screen should be selected to be put in the unit. If a 7/16-inch screen is not available, a 3/8-inch screen should be used.

ROLL CRUSHER SETTING

The top screen in a deck of screen has a two-fold purpose. First, it allows aggregate that is down to product size to pass through and fall down to the next screen. Secondly, it prevents material that is not down to product size from passing through the screen. Material that is not down to the product size passes off the end of the screen and normally is routed through the roll crusher. The roll crusher then crushes the oversize material down to the required product size.

Therefore, the distance between the roll shells, to include allowances for roll shell corrugations, must be set equal to the top product size. This distance is called the *product setting*. For example, as in the above problem, if the top product size is 3/4 inch, the product setting on the roll crusher (the distance between roll shells) should be 3/4 inch. *Top product size is the key to calibration of the roll crusher setting.*

The top product size and the top screen size dimensions should not be confused. If a 7/8-inch screen is selected to pass a top product size of 3/4 inch, as in the foregoing example, the product setting on the roll crusher is 3/4 inch and not 7/8 inch. The 7/8-inch screen was selected to compensate for screen inefficiency and not to produce a larger product size.

JAW CRUSHER SETTING

The last step in calibrating a plant is to set the jaw crusher. The product from the jaw crusher is directed to the screens. The screens reject all the jaw crusher product that is not down to the maximum product size desired. The oversize is sent to the roll crusher where it is further reduced in size so that it will meet maximum top size requirements. Therefore, the maximum size aggregate produced by the jaw crusher is dependent on the maximum size aggregate that the roll crusher can accept and crush effectively. After the maximum feed size to the roll crusher is determined, then the appropriate jaw crusher setting can be made.

The maximum feed size to the roll crusher determined by adding the product setting of the rolls to the stage of reduction capability for that particular set of rolls. Every different size of rolls and combination of roll shell surfaces is capable of a different stage of reduction. Table 3 gives the stage of reduction capability for various sizes of rolls and roll shell combinations.

TABLE 3. STAGE OF REDUCTION DUAL ROLL

Type of shell		*Stage of reduction*				
Stationary	*Floating*	*54" x 24"*	*40" x 22"*	*30" x 24"*	*30" x 18"*	*24" x 16"*
Coarse	Coarse	4"	3"			
Fine	Fine	3-1/2"	2-1/2"		2"	
Fine	Smooth	2-3/4"	2"	1-3/4"	1-1/4"	1"
Smooth	Smooth	2"	1-1/2"	1"	1"	3/4"

As in the above example, the product setting is 3/4 inch. For example, you know that the roll dimensions are 30 x 24 inches and that you have a fine corrugated and smooth roll shell combination. The stage of reduction capability for this particular set of rolls is 1-3/4 inches (Table 3). Therefore, the maximum feed size to the rolls is derived as follows:

Product Setting	3/4 inch
Stage of Reduction Capability	1-3/4 inches
	2-1/2 inches

This means that the product created by the jaw crusher should not be larger than 2-1/2 inches.

The jaw crusher is always set on the *closed stroke*. Therefore, allowance must be made for increased particle sizes when the jaw crusher is on the open stroke. Table 4 is used to determine the jaw setting required to produce a certain size aggregate. In the above example, the maximum size product created by the jaw crusher can be no larger than 2-1/2 inches. Therefore, from Table 4, you find the correct jaw setting will be 2-1/4 inches.

TABLE 4. JAW SETTING CHART

Jaw product	*Jaw setting*
10'	9"
9"	8"
8"	7"
7"	6"
6"	5"
5"	4"
4"	3-1/2"
3-1/2"	3"
3"	2-3/4"
2-3/4"	2-1/2"
2-1/2"	2-1/4"
2-1/4"	2"
2"	1-3/4"
1-3/4"	1-1/2"
1-1/2"	1-1/4"
1-1/4"	1"
1"	7/8"
7/8"	3/4"
3/4"	5/8"

Selecting jaw setting sizes: Select the next size lower on the jaw product size when the maximum size needed falls between two sizes on the chart. DO NOT INTERPOLATE THIS CHART. EXAMPLE: If the maximum jaw product size is found to be 3 3/4", select 3 1/2" from Table 4 and read the jaw setting at 3".

FINAL CALIBRATION

When you have completed the above steps the initial calibration of the plant is complete. This is an initial calibration and dependent on results from actual operation of the plant. Settings may be changed somewhat to achieve product sizes required. But, when making a change, do not forget to consider the relationship between the screens, roll crusher, and jaw crusher. A change in one component may necessitate a change in another component.

Learning Event 3
CALCULATING PLANT PRODUCTION

Once you have properly calibrated your plant, production will be maximized. Not much else can be done to improve the hourly output. For planning and estimation purposes, the remaining six steps of the production determination procedure must be accomplished to get an idea of what the production will be. This information is essential for your responsibilities as planner and manager.

JAW CRUSHER PRODUCTION RATE

The jaw crusher capacity depends upon the size of the jaw crusher, the type of rock being processed, and the product setting. In this example the jaw crusher size is 20 x 36 inches and you have already set the product setting at 2 1/4 inches. Table 5 can be used to determine the capacity of the jaw crusher.

TABLE 5. JAW CRUSHER CAPACITY (tons per hour)

Crusher size (inches)	*Setting of jaw at close of stroke (inches)*												
	1"	*1-1/4"*	*1-1/2"*	*2"*	*2-1/2"*	*3"*	*4"*	*5"*	*6"*	*7"*	*8"*	*9"*	*10"*
14 x 24	15	18	21	30	37	45							
15 x 24	. .	. . . .	21	30	43	62	80	100					
20 x 36	. .	. . . .	56	67	83	110	150	185	225				
30 x 42	. .	. . . .	. . . . .	. .	. . . . .	. .	200	250	300	350	400		

Capacity may vary by 25 percent.

Table 5 relates the unadjusted jaw crusher capacity in tons per hour to the crusher size and the jaw (or product) setting. Since there is no 2 1/4 inch reference in the table, interpolate the capacity as follows:

$$\frac{\text{Capacity @ 2 inches + Capacity @ 2 1/2 inches}}{2} =$$

$$\frac{67 \text{ tph} + 83 \text{ tph}}{2} = 75 \text{ tph @ 2 1/4 inches}$$

A production factor then must be applied to the 75 tph plant's jaw crusher capacity to compensate for the type rock being crushed. This is due to the fact that tough rock require more crushing time than more friable rock. Table 6 provides toughness factors and production factors for various types of rock. Assume the rock to be crushed is fine grained granite. From Table 6 the production factor is 0.80. Therefore the adjusted jaw capacity due to the toughness of the rock is:

75 tph x 0.80 = 60 tph

TABLE 6. RELATIVE TOUGHNESS OF ROCKS

Toughness		*Production factor*	
Limestone	1.0	1.0	
Dolomite	1.0	1.0	
Gneiss	1.0	0.95	(Coarse grained).
Syenite	1.0	0.95	
Andesite	1.2	0.90	
Slate	1.2	0.90	
Granite	1.2	0.90	(Coarse grained).
Chert	1.5	0.80	
Gabbro	1.6	0.80	
Quartzite	1.9	0.80	
Rhyilite	2.0	0.80	
Granite	2.1	0.80	(Fine grained).
Diorite	2.1	0.80	
Basalt	2.3	0.75	
Diabase	3.0	0.65	

Note. The includes maintenance factor.

ROLL CRUSHER PRODUCTION RATE

The roll crusher capacity depends on the size of the rolls, type of rock and the product setting. For example, you have a roll size of 30 inches by 24 inches with a product setting of 3/4 inch. Table 7 can be used to determine the roll capacity. From the table, 65 tons per hour is the unadjusted capacity for this example.

As in the case of the jaw crusher, a production factor must be applied to compensate for the type of rock being processed. In this example, you are crushing fine grained granite. Referring back to Table 6, the adjusted roll capacity is:

65 tph x 0.80 (from Table 6) = 52 tph.

TABLE 7. ROLL CRUSHER CAPACITY (tons per hour)

Crusher size	Maximum size of product									
	1/4"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	4"
54" x 24"	32	64	96	128	160	192	256	321	384	512
40" x 22"	24	48	72	95	118	143	190	238	287	
30" x 24"	27	44	65	85	110	125	175	219		
30" x 18"	16	33	49	66	82	98	131			
24" x 16"	13	26	39	52	65	78	104			

SIEVE ANALYSIS

After the production rates are determined for the jaw and roll crushers, the next step is to make a theoretical sieve analysis. This is to determine the percentage breakdown of the various sizes of material produced. It should be remembered that in any crushing operation, sizes will be produced from the maximum product size down to dust to include all sizes in between. The purpose of the sieve analysis is to calculate how many tons of various size aggregate will be produced from the *jaw crusher* action and the *roll crushing action*. From this the actual amount of product size aggregate (3/4 inch to 3/8 inch, in this example) that will be produced each hour can be determined.

The jaw crusher has been set to produce maximum size particles of 2 1/2 inches in the primary crushing operation of this example. But material ranging from 2 1/2 inches down to dust particles will result. The roll crusher has been similarly adjusted to produce particles ranging from 3/4 inch (top roll product size) down to dust. Tables 8 and 9 have been developed to show the percentage breakdown of each particle size produced based on the particular crusher setting.

Because the screens receive material from both crushers, a sieve analysis must be done for *both crushers*. Each particle size in the specifications from top product size down to the lowest specified size must be analyzed, plus material in the pan is included. NOTE: Pan is the by-product that goes through all the sieves but *must* be included in the sieve analysis for 100% of the aggregate crushed.

TABLE 8. OPEN CIRCUIT PRODUCT (jaw crusher)

SIZE RANGE	CRUSHER SETTING ON CLOSED STROKE																			
	1/4"	1/2"	3/4"	1"	1 1/4"	1 1/2"	1 3/4"	2"	2 1/4"	2 1/2"	2 3/4"	3"	3 1/2"	4"	5"	6"	7"	8"	9"	10"
+ 10"																				+10 .15
10" – 9"																			+9" .15	.32
9" – 8"																		+8" .15	.29	.09
8" – 7"																	+7" .15	.20	.06	.04
7" – 6"																+6" .15	.16	.09	.05	.04
6" – 5"															+5" .15	.13	.09	.06	.04	.03
5" – 4"														+4" .15	.10	.08	.07	.06	.05	.04
4" – 3 1/2"													+3½ .15	.09	.08	.08	.06	.05	.04	.03
3 1/2" – 3"												+3" .15	.08	.08	.08	.06	.06	.05	.05	.04
3" – 2 3/4"											+2¾ .15	.07	.06	.06	.05	.04	.03	.03	.03	.02
2 3/4" – 2 1/2"										+2½ .15	.07	.07	.07	.06	.05	.04	.03	.03	.02	.02
2 1/2" – 2 1/4"									+2¼" .15	.06	.06	.06	.06	.04	.03	.03	.03	.02	.02	.0
2 1/4" – 2"								+2" .15	.07	.07	.07	.07	.06	.05	.05	.04	.04	.03	.02	.02
2" – 1 3/4"							+1¾ .15	.08	.08	.08	.07	.06	.06	.06	.06	.05	.03	.03	.02	.01
1 3/4" – 1 1/2"						+1½ .15	.08	.07	.07	.07	.07	.06	.06	.06	.05	.04	.03	.02	.01	.01
1 1/2" – 1 1/4"					+1¼" .15	.09	.09	.08	.08	.07	.06	.06	.06	.05	.04	.03	.03	.02	.02	.01
*1 1/4" – 1"				+1" .15	.12	.11	.11	.10	.09	.09	.08	.07	.05	.04	.03	.03	.02	.02	.01	.01
1" – 7/8"				.07	.07	.06	.06	.06	.05	.05	.05	.05	.04	.03	.03	.03	.02	.02	.01	.01
7/8" – 3/4"			+3/4" .15	.08	.08	.07	.07	.07	.06	.05	.04	.03	.03	.03	.03	.02	.02	.01	.01	.01
3/4" – 5/8"			.10	.10	.07	.07	.06	.06	.06	.05	.04	.04	.04	.03	.03	.02	.02	.02	.02	.01
5/8" – 1/2"		+1/2" .15	.11	.10	.09	.08	.08	.06	.05	.04	.04	.04	.03	.03	.02	.02	.02	.01	.01	.01
1/2" – 3/8"		.15	.13	.10	.08	.08	.07	.06	.06	.06	.05	.05	.04	.04	.04	.03	.02	.02	.02	.01
3/8" – 5/16"		.10	.07	.06	.05	.04	.04	.04	.03	.03	.03	.02	.02	.02	.01	.01	.01	.01	.01	.01
5/16" – 1/4"	+1/4" .15	.09	.07	.05	.05	.05	.03	.03	.03	.03	.03	.02	.02	.02	.01	.01	.01	.01	.01	.01
1/4" – 4M	.15	.13	.08	.07	.05	.04	.04	.04	.03	.03	.03	.03	.03	.02	.02	.02	.02	.01	.01	.01
4M – 8M	.32	.15	.13	.09	.07	.06	.05	.03	.03	.02	.02	.02	.01	.01	.01	.01	.01	.01	.01	.01
8M – PAN	.38	.23	.16	.13	.12	.10	.07	.07	.06	.06	.04	.03	.03	.03	.03	.03	.02	.02	.01	.01

EXAMPLE: To find the percent of each size in the product of a crusher adjusted to 1 inch closed setting, find 1 inch at the top of the chart, follow the vertical column down until it intersects with the horizontal range size column. The first reading is 1 inch and 15% indicating that 15% of the material will be over 1 inch and 85% passing. By following down the vertical column we find the following:

Over 1”-15%	3/4”-5/8"-10%	3/8”-5/16”-6%	4M-8M - 9%
1”-7/8”-7%	5/8”-1/2”-10%	5/16”-1/4"-5%	-8 - 13%
7/8”-3 4”-8%	1/2”-3/8”-10%	1/4”-4M - 7%	TOTAL 100%

TABLE 9. CLOSED CIRCUIT PRODUCT (roll crusher)

SIZE RANGE	ROLL SETTING													
	1/4"	1/2"	3/4"	1"	1 1/4"	1 1/2"	1 3/4"	2"	2 1/4"	2 1/2"	2 3/4"	3"	3 1/2"	4"
4" – 3 1/2"														.10
3 1/2" – 3"													.09	.09
3" – 2 3/4"												.08	.07	.07
2 3/4" – 2 1/2"											.08	.08	.08	.07
2 1/2" – 2 1/4"										.07	.07	.07	.07	.05
2 1/4" – 2"									.08	.08	.08	.08	.07	.06
2" – 1 3/4"								.09	.09	.09	.08	.07	.07	.07
1 3/4" – 1 1/2"							.09	.08	.08	.08	.08	.07	.07	.07
1 1/2" – 1 1/4"						.11	.11	.09	.09	.08	.07	.07	.07	.06
1 1/4" – 1"					.14	.13	.13	.12	.11	.11	.09	.08	.06	.05
1" – 7/8"				.08	.08	.07	.07	.07	.06	.06	.06	.06	.05	.04
7/8" – 3/4"				.09	.10	.08	.08	.08	.07	.06	.05	.04	.04	.03
3/4" – 5/8"			.12	.12	.08	.08	.07	.07	.07	.06	.05	.05	.05	.04
5/8" – 1/2"			.13	.12	.11	.09	.09	.07	.06	.05	.05	.05	.04	.04
1/2" – 3/8"		.18	.15	.12	.09	.09	.08	.07	.07	.07	.06	.06	.05	.05
3/8" – 5/16"		.12	.08	.07	.06	.05	.05	.05	.04	.04	.04	.02	.02	.02
5/16" – 1/4"		.10	.08	.07	.06	.06	.04	.04	.03	.03	.03	.02	.02	.02
1/4" – 4M	.18	.15	.10	.07	.06	.05	.05	.05	.04	.04	.04	.04	.03	.02
4M – 8M	.38	.18	.15	.11	.08	.07	.06	.04	.04	.02	.02	.02	.01	.01
8 M – PAN	.44	.27	.19	.15	.14	.12	.08	.08	.07	.06	.05	.04	04	.04

EXAMPLE: To find the percent of each size in the product of a crusher set to produce 3/4 inch material in closed circuit, find 3/4 inch at the top of the chart, follow the vertical column down until it intersects with the horizontal size range column and we find:

3/4”-5/8”-12%	3/8”-5/16”-8%	4M-8M - 15%
5/8"-1/2”-13%	5/16"-1/4"-8%	-8 - 19%
1/2”-3/8”-15%	1/4"-4M - 10%	TOTAL 100%

Material larger than the roll top product size must be considered. This material must go to the roll crusher, so its capacity must be checked against the input rate. The amount of material is found by using Table 8, Open Circuit Production, since the material comes from the jaw crusher.

Table 8 is used when crushing is being done in an open circuit system such as the jaw crusher. Table 9 is used with a closed circuit system, such as a roll crusher, where the material is being screened prior to crushing and then recirculated back to the screens after it is crushed in the roll crusher. Figures in the left hand column of the charts indicate size ranges. Figures across the top of the charts represent crusher settings. To read the chart, locate the size range to be considered, and then locate the crusher setting column. Intersect the size range row with the crusher setting column to find the percentage of material that will fall in that size range due to the crushing action at that particular crusher setting.

Example: Intersect the row and column marked with an asterisk on Table 8. With a 1 1/4 inch setting, 12 percent of the crushed product will be in the 1 1/4 inch to 1 inch size range. Table 9 is read and used in the same way as Table 8.

Remember, you set the Jaw crusher at 2 1/4 inches and specified the, top product size at 3/4 inch. To find the percentage of oversize particles add up all decimal fractions in the 2 1/4 inch crusher setting column, of Table 8, which are greater than 3/4 inch in size (under size range locate the 7/8 inch to 3/4 inch row). Intersect the crusher setting column and the size range row. Add up the percentages in each size range above and including the 7/8 inch to 3/4 inch size range as follows:

Size Range	Percentage
7/8"- 3/4"	0.06
1" - 7/8"	0.05
1 1/4"- 1"	0.09
1 1/2" - 1 1/4"	0.08
1 3/4"- 1 1/2"	0.07
2" - 1 3/4"	0.08
2 1/4" - 2"	0.07
+2 1/4"	0.15
	0.65 =65%

(NOTE: + means "greater than.")

This means that 65% of the production from the jaw crusher, which you calculated at 60 tons per hour, must go to the roll crusher for further processing. Thus: 0.65 x 60 tph = 39 tph. This means that 39 tons per hour produced by the jaw crusher will be larger than 3/4 inch and must be sent to the roll crusher for further processing. Continuing to use Table 8, 11%

(.06 + .05) of the product will be larger than 1/2 inch and smaller than 3/4 inch, 6% (.06) of the product will be larger than 3/8 inch and smaller than 1/2 inch, 9% (.03 +.03 +.03) of the product will be larger than No. 4 and smaller than 3/8 inch, and 9% (.03 +.06) will be from No. 4 down to microscopic dust. Note that adding 65% + 11 % +6% + 9% + 9% = 100%. This addition can be used to double check figures.

Set up a table which lists size range, jaw crusher, roll crusher, and totals. It should look like this example.

Size range	*Jaw crusher @ 60 tph*	*Roll crusher @ 39 tph*	*Total tph jaw + roll*
+ 3/4	60 tph x 65% = 39 tph		
+ 1/2	60 tph x 11% = 6.6 tph	39 tph x 25% = 9.75 tph	16.35
+ 3/8	60 tph x 6% = 3.6 tph	39 tph x 15% = 5.85 tph	9.45
+ No. 4	60 tph x 9% = 5.4 tph	39 tph x 26% = 10.14 tph	15.55
+ PAN	60 tph x 9% = 5.4 tph	39 tph x 34% = 13.26 tph	18.65
Totals	60 tph x 100% = 60 tph	39 tph x 100% = 39 tph	60 tph

Note. All of the product of the jaw crusher that is over 3/4 inch (39 tph) will go to the roll crusher.

The column for the roll crusher breakdown was based on the 39 tons per hour of oversize found previously. Using Table 9, for the roll crusher, which receives 39 tons per hour of +3/4 inch material, 25% (.13 + .12) of the product will be larger than 1/2 inch, 15% (.15) of the product will be larger than 3/8 inch and smaller than 1/2 inch. Similarly 26% (.10 + .08 + .08) of the product will be larger than No. 4 and smaller than 3/8 inch and 34% (.15 +.19) will be from No. 4 down to microscopic dust. Notice that adding 25% + 15% +26% + 34% = 100%. This addition can be used to double check figures. Summing across the row, you now have the breakdown in tons per hour for the crushing equipment.

Go back and review your top and bottom product size range and summarize your sieve analysis results as follows:

Product Size	Tons	By-Product Size	Tons
+ 1/2"	16.35	+ #4	15.55
+ 3/8"	9.45	Pan	18.65
TOTAL Product	25.80	TOTAL By-Product	34.20

INITIAL GRADATION CHECK

Once the tonnages in each size range have been estimated, you can check the expected product for compliance with product specification. Tabular form is the most graphic method for a gradation check. Product in this example falls in the size category from 3/4 inch to 3/8 inch, and the reminder is byproduct. From the sieve analysis, there are 25.80 tons of product produced each hour, and 34.20 tons of by-product. *The gradation is determined by taking the tonnage produced in each size range divided by the total product tonnage, which gives the percent retained.* This percent retained is the portion of the product which would not pass through the screen corresponding to the specified size range. It is the percentage produced which is larger than the specified size.

GRADATION CHECK

Size	$\frac{\text{TPH Produced @ Size}}{\text{Total TPH Produced}}$ (× 100%)	= % Retained	% Passing
+ 1"	$\frac{0}{25.80}$ (× 100%)	= 0%	100% − 0% = 100%
+ 3/4"	$\frac{0}{25.80}$ (× 100%)	= 0%	100% − 0% = 100%
+ 1/2"	$\frac{16.35}{25.80}$ (× 100%)	= 63%	100% − 63% = 37%
+ 3/8"	$\frac{9.45}{25.80}$ (× 100%)	= 37%	37% − 37% = 0%

Percent passing is then the difference between the percent passing of the previously larger range and the percent retained for the desired size range. When starting the process at the largest size range, subtract the percent retained from 100 percent.

Check the percent passing for each size against corresponding product specifications. In this case, you have met the specifications.

SCREEN CAPACITY

The last equipment component to be checked is the screen assembly. Each screen must be checked to determine whether or not the screen can handle the input flow to it. The larger the screen opening, the higher the capacity will be.

The following formula is used to determine the capacity of a screen:

$$Q = B \times A \times D \times H \times O \times W$$

Q = *Quantity of material* in tons per hour the screen can process.

B = *Basic capacity* of one square foot of screen cloth (Table 10) in tons per hour. For example: one square foot of 1 1/2-inch screen cloth has the ability to let 2.7 tons of crusher run rock pass through it in one hour. A 1 1/2-inch screen has the ability to pass 3.2 tph of gravel run material. The increase in production is due to the more rounded particle shapes found in gravel deposits. Rounded particles will pass through a screen more readily than angular particles.

TABLE 10. BASIC CAPACITY, B (tons/hour/square foot)

Product size	No. 8	No. 4	3/8"	1/2"	5/8"	3/4"	7/8"	1"	1-1/2"	2"	2-1/2"	3"	4"
Crusher run. . .	.5	.9	1.2	1.4	1.6	1.7	1.9	2.1	2.7	3.1	3.4	3.7	4.0
Gravel	.8	1.0	1.4	1.7	1.9	2.1	2.4	2.5	3.2	3.7	4.0	4.4	4.8

A = *Area of screen deck* in square feet. Table 11 gives square footage measurements on various military crushing plants.

TABLE 11. SCREEN SIZE CHART, A (in square feet)

Type of plant	*Screen size*
35 tph crushing and screening plant:	
1st Deck	**24 sq ft**
2nd Deck	**24 sq ft**
75 tph crushing and screening plant	
Scalper (primary unit):	
1st Deck	**18 sq ft**
2nd Deck	**15 sq ft**
Screen (secondary unit):	
1st Deck	**40 sq ft**
2nd Deck	**40 sq ft**
75 tph washing and screening plant:	
All 40 sq ft	
225 tph crushing and screening plant:	
Primary unit (153 PRD):	
Bar grizzly only	
Intermediate unit (54 VDE):	
1st Deck	**48 sq ft**
2nd Deck	**48 sq ft**
3rd Deck	**40 sq ft**
4th Deck	**24 sq ft**
Crushing, screening, and washing unit (300 WDE):	
1st Deck	**53 sq ft**
2nd Deck	**53 sq ft**
Intermediate unit (42 VDE):	
1st Deck	**32 sq ft**
2nd Deck	**32 sq ft**

D = *Deck position factor* (Table 12). The lower a screen is in a deck of screens, the lower the capacity of that screen will be. This is because the aggregate going across the first deck of a set of screens works down the total length of the screen. But as the aggregate passes through the top screen and down to the second screen, it does not fall on the leading end of the second screen, but rather part way down from the leading end. As a result the aggregate failing on the second screen does not travel across the total length of the screen. Therefore, the capacity of the second screen is reduced. The same holds true for the third and fourth screens of a deck of screens.

H = *Halfsize material.* This is the aggregate in the feed that is half the top size of the aggregate that the screen is supposed to pass (Table 12). For example, if a screen is installed to screen out a maximum size aggregate of 10 inches, then all material in the feed 5 inches or less is 1/2 size ag-

TABLE 12. SCREEN CORRECTION FACTORS							
D		H		W		O	
Correction for number of decks above		Aggregate 1/2 screen product		Washing factor		Aggregate over screen product	
Deck	Factor	Percentage	Factor	Product	Factor	Percentage	Factor
1st	1.0	10%	0.5	1"	1.25	10%	1.05
2nd	0.9	20%	0.7	3/4"	1.50	20%	1.01
3rd	0.8	30%	0.8	1/2"	1.75	30%	.98
4th	0.7	40%	1.0	3/8"	2.50	40%	.95
		50%	1.2	1/4"	3.00	50%	.90
		60%	1.4	No. 4	3.50	60%	.85
		70%	1.8	No		70%	.80
		80%	2.2	Washing	1.00	80%	.70
		90%	3.0			90%	.55

Note: Interpolate percentages in columns H and O if required. For example: 15% aggregate of 1/2 screen product will have an H factor of 0.6.

gregate. As the percentage of 1/2 size aggregate in the feed is increased, the capacity of the screen will increase. This is because 1/2 size aggregate will pass through the screen openings much more readily than aggregate greater than 1/2 size aggregate.

O = *Oversize material.* This is the aggregate (Table 12) that is too large to pass through a screen. As the percentage of oversize aggregate in the feed is increased, the capacity of the screen will decrease. This is due to the fact that the oversize particles, being heavier than the smaller particles, will fall to the bottom of the bed of rock going across the screen. Since they are too large to pass through the screen, they tend to prevent the smaller parties from passing through.

W = *Washing factor* (Table 12). When aggregate is sprayed with water as it passes across a screen, the capacity of the screen will be increased. This is because the water will lubricate the outer surfaces of the aggregate, thereby causing the aggregate to pass through a screen more readily than if it were dry. When washing is not employed, a factor of 1 is used for the washing factor. Washing is most effective in the smaller size ranges. As the aggregate size is increased, the advantage of washing is decreased. Care should be taken in washing operations in that too little water will not flush out the dirt and mud washed off the rock. If too little water is used this dirt and mud may clog up the screens thereby decreasing the screen capacity.

Lesson 2/learning Event 3

Considering the example described in this lesson, the determination of screen capacities would be as follows (assume both screens are 40 square feet in area).

Top Screen = 3/4 inch
Q = B x A x D x H x O x W
B = 1.7 tph (Table 10)
A = 40 feet (Table 11)
D = 1.0 (Table 12)
H = 0.9 (Table 12), which is found as follows: 3/4" x 1/2 = 3/8" is the halfsize (see explanation below).

Tonnages can be found from the sieve analysis of the total product. In this case there are 34.2 tons in this range.

+ # 4	=	15.55 tph
PAN	=	18.65 tph
		34.20 tph

The flow into the top screen is the sum of the total jaw crusher output and the roll crusher output, or 60 tph + 39 tph = 99 tph. This is because 21 tons of the 60 tons pass through the top screen and 39 tons go to the roll crusher for further processing. Percent halfsize is then:

$$\frac{\text{amount of halfsize}}{\text{total load}} \times 100\% = \frac{34.20 \text{ tph}}{99 \text{ tph}} \times 100\% = 34.6\%$$

The corresponding factor, H, is found by interpolation from Table 12 to be 0.90.

Oversize (O) is all material over 3/4 inch. The oversize factor is similarly found from percentage oversize using information from the sieve analysis. Remember that for the top screen, whatever goes to the roll crusher (in essence rejected) is oversize. Of the total screen load of 99 tph, 39 tph is oversize and must be sent to the roll crusher:

$$\frac{\text{oversize material}}{\text{total load}} \times 100\% = \frac{39 \text{ tph}}{99 \text{ tph}} \times 100\% = 39.4\%$$

From Table 12, by interpolation, the oversize factor when 39.4 percent of the feed is oversize equals 0.95. Washing is not being done, so a factor of 1.0 is used (Table 12).

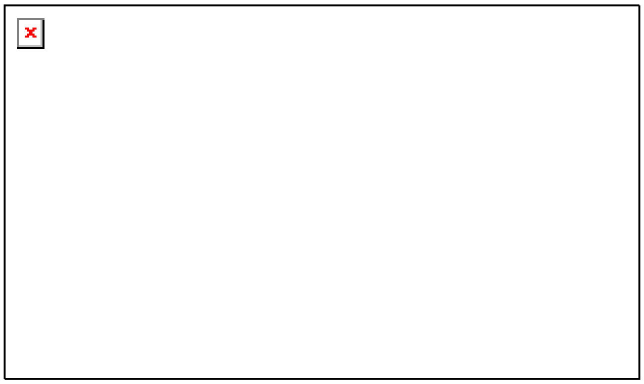
Therefore, for the top screen:

Q = B x A x D x H x O x W
Where: B = 1.7, A = 40, D = 1.0, H = 0.9, O = 0.95, W = 1.0
Q = (1.7) x (40) x (1.0) x (0.9) x (0.95) x (1.0) = 58.2 tph.

The top screen has the ability to screen out 58.2 tph. The screen must be able to let 60 tons pass through each hour to keep up with the jaw crusher produc-

tion. Because the charts used to determine screen capacity are based on empirical data, there may be fluctuations between these calculated results and actual field performance. Therefore, for planning purposes, it may be assumed that the top screen will be able to handle the 60 tons per hour and is acceptable.

The capacity of the bottom screen is calculated similarly. (In other screening operations, intermediate screen capacities are also calculated in this manner.) Remember that the bottom screen must have the capacity to handle the total by-product, or 34.2 tons per hour in this example. Halfsize for the bottom screen is tonnage of product up to and including #4.



Therefore:

$$Q = B \times A \times D \times H \times O \times W \text{ (Values given above.)}$$
$$= (1.2) \times (40) \times (0.9) \times (0.81) \times (0.93) \times (1.0) = 32.6 \text{ tph}$$

The bottom screen is able to remove only 32.6 tph of the by-product, while the demand is 34.2 tph. Although the difference between the demand, 34.2 tph and the capacity, 32.6 tph is not great, the worst case must be considered rather than say, “close enough.” Therefore 1.6 tph of by-product (34.2 - 32.6) = 1.6 tph does not get screened out and is retained in the product stockpile. Therefore, the actual product is 27.4 tph (25.8 + 1.6 = 27.4 tph).

Lesson 2/Learning Event 3

FINAL GRADATION CHECK

Since the new product contains an additional 1.6 tons per hour of by-product size material, a final gradation check must be made. The new product is increased to 27.4 tons per hour.

Size	$\frac{\text{tph produced @ size}}{\text{total tph produced}}$ (× 100%)	= % retained	% Passing
+1"	$\frac{0}{27.4}$ (× 100%)	= 0%	100% − 0% = 100%
+3/4"	$\frac{0}{27.4}$ (× 100%)	= 0%	100% − 0% = 100%
+1/2"	$\frac{16.35}{27.4}$ (× 100%)	= 59%	100% − 59% = 41%
+3/8"	$\frac{9.45}{27.4}$ (× 100%)	= 34%	41% − 34% = 7%
+#4	$\frac{0.80}{27.4}$ (× 100%)	= 3.5%	7% − 3.5% = 3.5%

Because the new product contains more particles than originally anticipated in the 3/8 inch size, #4 has been included in the gradation check. Assume that one-half of the 1.6 tons of by-product in the product stockpile is + #4 aggregate and one-half is smaller than #4 aggregate. Thus, the 0.8 tph is found in the + #4 row in the table above. Checking against your product specifications,

Size	Percent Passing
1-inch	100 percent
3/4-inch	90-100 percent
1/2-inch	20-50 percent
3/8-inch	0-15 percent
# 4	0-15 percent

you find that the specifications will be met. The estimated production range is 27.4 tph of usable product.

PRACTICE EXERCISE FOR LESSON 2

Instructions

You have just finished reading the instructional material for Lesson 2. Check your understanding of the lesson by completing the following practice exercise. Try to answer all of the questions without referring to the lesson material.

When you have completed all of the questions, turn the page and check your answers against the correct responses. Each correct response is referenced to specific portions of the lesson material so that you can review any questions you have missed or do not understand. When you have completed this practice exercise, you should review all of the subcourse material before starting the examination.

1. List three variables that influence quarry crushing plant production rates.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. The Commander of a rock crushing plant is responsible for the following duties:

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

   h. ______________________________

   c. ______________________________

Use the following information to answer questions 3 through 10.

Your CO tells you that your unit's new mission is to produce a stockpile of aggregate for future concrete construction work. He asks you to determine

your unit's capacity to produce the aggregate if there are two 75-tph rock crushing plants available. Production must meet the following specifications:

Size	Percent Passing
2”	100%
1 3/4”	90-100%
1 1/4"	50-80%
3/4”	30-55%
1/2”	10-40%
3/8”	0-15%
1/4”	0-5%

The quarry rock is fine-grained granite rock. The shell-types in the rolls are both fine corrugated and smooth (FC/S). Roll crushers are 30 by 24 inches. Jaw crushers are 20 by 36 inches. There is one secondary unit in each plant, no washing.

3. Select your top and bottom screens.

____

____

4. What should your roll crusher setting be? Give the product setting, stage of reduction, and maximum feed size.

____

____

5. What should you se the jaw crusher at?

____

6. Determine the jaw crusher production. Give the material hardness production factor and the jaw capacity.

____

____

7. Calculate the roil crusher production.

____

8. Complete the following sieve analysis.

Size	Jaw Crusher (88 tph)		Roll Crusher (42.24 tph)		Total (tph)
+1¾"	.48 × 88 = 42.24				
+1¼"	____	____	.20 × 42.24 =	8.45	19.01
+7/8" (half size)	.12	____	.20	____	____
+¾"	____	2.64	______	3.38	6.02
+½"	.08	____	.16	____	13.80
+3/8"	____	4.4	______	3.38	____
+¼"	.04	____	.09	____	7.32
+#4	____	2.64	______	2.11	____
PAN	____	____	.14	____	10.31
	100%	88 tph	100%	42.24 tph	88 tph

Product __________________ = __________ tph

By-Product __________________ = __________ tph

9. Complete the following gradation check table.

Size		% Retained	% Passing
2"	0/65.62 × 100	= 0	100
______________________		= 0	100
+1 ¼"	19.01/65.62 × 100	= ______	71.03
______________________		= ______	________
+¾"	6.02/65.62 × 100	= 9.17	32.89
+½"	13.80/65.62 × 100	= 21.03	________
+3/8"	7.78/65.62 × 100	= ______	0

10. Figure out the screen capacity for your top screen.

11. Figure out your bottom screen capacity. Is there an excess demand?

____

____

12. Complete the following final gradation check. What is your total new product (in tph) for your complex? Have you met your specifications?

Size	% Retained	% Passing
+1 3/4”		
+1 1/4”		
+7/8”		
+3/4”		
+3/8”		
+1/4”		

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Lesson 2
ANSWER SHEET FOR PRACTICE EXERCISE

1. a. Type of rock being crushed
   b. Feed size of raw material
   c. Size of finished product desired

2. a. Assignment of rock crushing tasks
   b. Adequate lead time for rock crushing plant design and erection
   c. Maintenance of equipment and facilities
   d. Coordinate quarry and rock crushing operations
   e. Calculate production rates
   f. Establish priorities of aggregates
   g. Record rock crushing operations statistics
   h. Evaluate rock crushing operations

3. Top screen for 1 3/4 inch aggregate is a 2 inch screen.
   Bottom screen for 3/8 inch aggregate is a 7/16 inch screen.

4. Product setting is 1 3/4 inch roll crusher setting
   Stage of reduction is 1 3/4 inches
   Maximum feed size is 3 1/2 inches by adding product setting and stage of reduction.

5. Jaw setting for 3 1/2 inches jaw crusher product is 3 inches.

6. a. Jaw capacity (20 x 36 in.) is 110 for 8 inch jaw setting (Table 5).
   b. Material hardness production factor is 0.80 for fine-grained granite (Table 6).
   c. Calculate 110 x 0.80 = 88 tph.

7. a. Interpolate roll crusher capacity from Table 7 (p.55) for 30 x 24 inch rollers. Product site is 1 3/4 inches, which is halfway between 1 1/2 and 2 inches. Calculate (125 tph + 175 tph) + 2 = 150 tph.
   b. The material hardness production factor is 0.80 (Table 6).
   c. Calculation:
      Roll crusher capacity x hardness factor = capacity in tph
      150 tph x 0.80 = 120 tph

8. Completed sieve analysis table:

Size	Jaw Crusher (88 tph)		Roll Crusher (42.24 tph)		Total (tph)
+1 3/4	.48 × 88 =	42.24			
+1 1/4	.12	10.56	.20 × 42.24 =	8.45	19.01
+7/8 (halfsize)	.12	10.56	.20	8.45	19.01
+3/4	.03	2.64	.08	3.38	6.02
+1/2	.08	7.04	.16	6.76	13.80
+3/8	.05	4.4	.08	3.38	7.78
+1/4	.04	3.52	.09	3.80	7.32
+#4	.03	2.64	.05	2.11	4.75
PAN	.05	4.4	.14	5.91	10.31
	100%	88	100%	42.24	88

Product = (7.78 + 13.8 + 6.02 + 19.01 + 19.01) = 65.62-tph

By-Product = (7.32 + 4.75 + 10.31) = 22.38 tph

9. Complete gradation check table:

Size		% Retained	% Passing
2"	0/65.62 × 100	= 0	100
+1 3/4"	0/65.62 × 100	= 0	100
+1 1/4"	19.01/65.62 × 100	= 28.97	71.03
+7/8"	19.01/65.62 × 100	= 28.97	42.06
+3/4"	6.02/65.62 × 100	= 9.17	32.89
+1/2"	13.80/65.62 × 100	= 21.03	11.86
+3/8"	7.78/65.62 × 100	= 11.86	0

10. Top screen capacity (O) is 109.14 tph.

Top Screen:

Top Product Size = 1 3/4 inches; Half-Product Size = 7/8 inch and below. Q = B × A × D × H × O × W.

$B = \frac{2.7 + 3.1}{2}$ = 2.9 tph/square foot for 1 3/4-inch crusher run material.

A = 40 square feet for the first deck of a 75-tph secondary unit.

D = 1.0 for first deck.

$\text{Percent Halfsize} = \frac{6.02 + 13.8 + 7.78 + 7.32 + 15.06}{88 + 42.24} \times 100 = 38.4\%$

H = 0.97

$\text{Percent Oversize} = \frac{42.24}{130.24} \times 100 = 32.4\%$

O = 0.97

W = 1.0 (no washing)

Q (top screen) = 2.9 × 40 × 1 × 0.97 × 0.97 × 1 = 109.14 tph

11. Bottom screen capacity (Q) is 17.17 tph.

Bottom Screen:

Bottom Product Size = 3/8-inch aggregate; Half-Product Size = #4 and below.
B = 1.2 tph/square foot for 3/8-inch crusher run material.
A = 40 square feet for the second deck of a 75-tph secondary unit.
D = 0.9 for second deck.

$\text{Percent Halfsize} = \frac{10.31}{88} \times 100 = 11.7\%$

H = 0.53

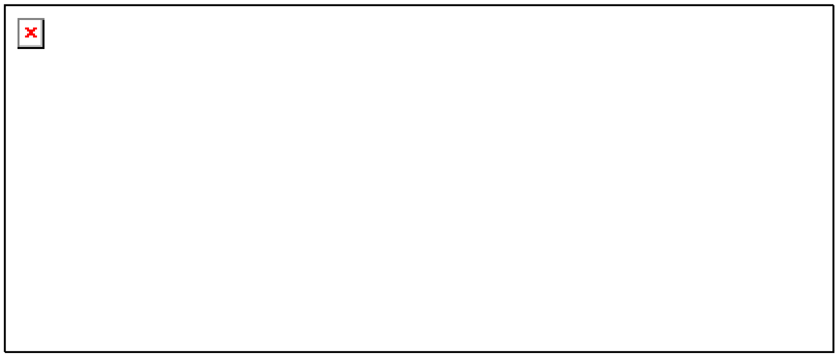
$\text{Percent Oversize} = \frac{65.62}{88} \times 100 = 74.6\%$

O = 0.75
W = 1.0 (no washing)
O (bottom screen) = 1.2 x 40 x 0.9 x 0.53 x 0.75 x 1 = 17.17 tph

By-Product Demand	22.38
Screen Capacity	17.17
Excess Demand	5.21 tph

Yes, there is an excess demand of 21 tph.

12. Final gradation check:



Your new product is 70.83 tph, calculated 5.21 tph + 65.62 tph = 70.83 tph, for each 75-tph plant. *Therefore, your total new product for your complex is 141.66 tph, calculated 2 x 70.83 tph = 141.66 tph (you have two 75-tph plants, remember). Your specifications are met.*

Note: Assume that one-half of the 5.21 TPH by-product is +1/4 and one-half is smaller than 1/4 inch aggregate. That is why 5.21 x 0.5/70.83 x 100 = 3.68